IAEA

International Atomic Energy Agency

Nuclear Power Human Resources Modelling Tool

Description and User Manual

VIENNA, 2021

TRAINING COURSE SERIES 73

NUCLEAR POWER HUMAN RESOURCES MODELLING TOOL

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DESCRIPTION AND USER MANUAL

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2021

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FOREWORD

The IAEA's Nuclear Power Human Resource modelling tool was created to assist Member States in developing their human resource plans and requirements for new nuclear power programmes. The tool allows a country to examine their capacity to meet human resource requirements. The modelling tool enables hands-on experience for analysts supporting human resource planning and other technical specialists from governmental organizations, operating organizations and the nuclear industry of Member States implementing nuclear power programmes. Its objective is to analyse the nuclear power workforce in key organizations involved in nuclear power programme development — namely, the nuclear energy programme implementing organization, the owner/operator, and the regulatory body — while taking into account existing national workforces and respective educational systems.

Together with management and development of the model, the IAEA regularly provides training workshops to tailor the model to a Member State's needs with respect to national circumstances and objectives.

This publication provides detailed explanations of the initial data needed to gain a comprehensive understanding of the Nuclear Power Human Resource modelling tool and summarizes each of the simulator tabs, modifiable worksheets and various controls. A complete description of all the modelling tool's features is also provided. A detailed set of examples is provided in the appendices.

The IAEA gratefully acknowledges the contribution of K. Kern (United States of America) to the preparation of this publication. The IAEA officer responsible for this publication was N. Kurova-Chernavina of the Division of Nuclear Power.

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1. INTRODUCTION

1.1. BACKGROUND

The Nuclear Power Human Resource (NPHR) modelling tool is based on the IAEA Milestones Approach outlined in Milestones in the Development of a National Infrastructure for Nuclear Power, IAEA Nuclear Energy Series No. NG-G-3.1 (first published in 2007 and revised in 2015) [1]. It is focused on the key organizations in a nuclear power programme, namely the Nuclear Energy Programme Implementing Organization, the owner/operator, the regulatory body and the Engineering, Procurement and Construction (EPC) contractor. The workforce for these organizations is part of a national workforce that includes other industrial sectors that share skills in common with nuclear power, Technical Support Organizations (TSOs) that provide services to the nuclear power programme, and other nuclear sectors that require similar expertise. The overall national nuclear power programme workforce is supported by the national educational system. Workforce dynamics include workers entering the workforce, potentially changing careers between different economic sectors, advancing careers, and ultimately leaving the workforce. The modelling tool is designed, therefore, to analyze the workforce needed for nuclear power programme at a national level.

The tool runs in the commercially available systems dynamics software Stella Architect™ marketed by iSee Systems, Inc. A licence for Stella Architect™ is required for working with the model. The model uses a Microsoft Excel spreadsheet (*.xls or *.xlsx) as an external data file.

1.2. OBJECTIVE

The purpose of this document is to provide a step-by-step guide to setting up and using the NPHR modelling tool. The NPHR modelling tool is a system dynamics simulation that is used to examine the human resource requirements and the capacity of a country to meet those requirements of a nuclear power programme.

1.3. SCOPE

The scope of this manual is to:

- Introduce the NPHR modelling tool and related files;
- Give instructions on how to install the NPHR modelling tool;
- Explain how to configure the data in the NPHR modelling tool for a specific nuclear power programme;
- Describe how to set up and run the NPHR modelling tool.

The NPHR modelling tool may be used to answer questions such as:

- What enhancements to a national educational system are needed to prepare the workforce for nuclear power programme?
- What competition is anticipated for skilled workers (specialists, engineers, etc.) for the nuclear power programme?
- How can experience in other economic sectors be used to help create and form the key organizations for nuclear power programme?

- What decisions related to contracting with a vendor affect the workforce planning and dynamics?

The NPHR modelling tool comes configured for a representative nuclear power programme. The initial settings help adjust model parameters for a specific plan. The model includes a data file for populating it with data specific to a country. Finally, the model can be extended and enhanced to include other scope of interest to a national nuclear power programme, and customized output.

1.4. STRUCTURE

This manual covers the following topics:

- Section 2 gives instructions on installation of the NPHR modelling tool;
- Section 3 provides a reference table of data for the NPHR modelling tool;
- Section 4 discusses the data file;
- Section 5 gives instructions on how to run the NPHR modelling tool;
- Finally, technical details of the NPHR modelling tool calculations are provided in seven Appendices.

Configuration of the NPHR modelling tool for a nuclear power programme is done primarily through a spreadsheet data file which is to be populated with national data. The data file is then imported into the model. It is operated through a user interface in which various parameters representing decisions within the nuclear power programme are adjusted. Before producing meaningful results, the data file and all model interface settings are to be configured for the specific nuclear power programme.

Technical details of the NPHR modelling tool are found in Appendix. These Appendices contain discussion of the calculations within the NPHR modelling tool. Familiarity with Stella Architect™ or another system dynamics modelling environment is needed to understand the technical documentation.

Any additional files related to the NPHR modelling tool (including images and NPHR spreadsheets) can found on the IAEA Nuclear Infrastructure Development Section (NIDS) Interactive Platform (Capacity Building folder) if not specified otherwise.

The text format in this document is used the following way:

- *Text* – titles of NPHR modelling tool worksheets, pages, sub-pages and modules;
- **Text** – titles of NPHR modelling tool controls and buttons;
- ***Italics and bold*** – titles of variables and NPHR functions.

2. INSTALLATION

The NPHR modelling tool is developed in the Stella Architect™ environment. It requires installation of the Stella Architect™ software and the NPHR model files.

Stella Architect™ is a commercial software package available from iSee Systems, Inc. (iSeeSystems.com). Registration and purchase of a licence is required before downloading the software from the iSee Systems website. For licensing options the IAEA NIDS could be contacted (NIDS.Contact-point@IAEA.org).

The NPHR modelling tool is provided by the IAEA via the Nuclear Infrastructure Development Section Interactive Platform. To gain access to the platform and model files, email NIDS.Contact-point@IAEA.org.

To download the latest version of the NPHR modelling tool (NPHR V3.0) from the IAEA NIDS Interactive Platform, do the following:

- On the computer create a folder for the NPHR modelling tool (e.g. NPHR V3.0);
- In this folder create a sub-folder called NPHR3.0_Modules;
- Open the Interactive Portal and navigate to Downloads, then Version 3.0;
- Copy the two files NPHR3.0.stmx and NPHR3.0.isdb to the main folder;
- On the Interactive Platform, open the NPHR3.0_Modules folder;
- Copy the five files to the folder NPHR3.0_Modules on your computer;
- Navigate back to the top folder and double click NPHR3.0.stmx;
- In addition, copy the data file Workforce Data Revised 2019.xlxs.

Important notes:

- One might have to select each file individually for download;
- The sub-folder name is to match the folder name on the Interactive Platform including the underscore '_'.

3. NPHR MODELLING TOOL DATA DEFINITIONS

This section contains definitions for the data used in the latest version of the NPHR modelling tool. The data are maintained in the Excel data file *Workforce Data Revised 2019.xlxs*, which is discussed in the next section. It is necessary to use the definitions in this section along with the technical documentation for the NPHR modelling tool to gain an understanding of each factor and how it is used. This will help ensure that data used in the model is the correct value and form. In the NPHR V3.0 files, which run within Stella Architect™, any model element that contains a constant from the external data file is shaded in yellow.

General notes:

- Variable names are in the form required for importing into the NPHR modelling tool. It is crucially important that capitalization and spelling match the use in the model with spaces replaced by the underscore character '_'.
- Rates are expressed as decimal fractions of a total. Rates are not expressed as percentages to prevent confusion. For example, if 10% of a group retire, the rate or fraction used in the model will be 0.10. In the model and in this document, the term fraction will refer to a decimal expression of a rate.
- Not all data need to be updated. Variables related to the staffing models are representative of a typical operating or construction organization rather than characteristics of a national workforce. These do not need to be changed unless the user is developing new staff models.
- Enrolment and population data is set for 2015 or needs to match to the year the simulation will start if that has been changed from 2015 to a different year. Rates are projections going forward.
- Variables ending with brackets [] are arrays and require multiple values in a string format, such as 1,2,3,4.
- It is recommended to gain a complete understanding of how data are used in the model to ensure understanding of the data requirements. For this reason, technical documentation is included in the appendices.

Table 4 contains definitions for the data used in the NPHR modelling tool.

4. THE NPHR MODELLING TOOL DATA FILE

Data for use in the NPHR modelling tool is managed in an Excel spreadsheet called *Workforce Data.xlsx*. The NPHR modelling tool uses data from many data sources which may not be in the format expected by the model. It is also important to be able to quickly and easily review the data that form the basis of an analysis. Using an Excel data file allows the data to be easily seen, organized, and translated into the desired format for the model to use. It also allows collection of multiple data sets so that scenarios may be developed and compared. Once the data are imported, the controls in the model may be used to choose between options or make small variations to the data.

4.1. AN IMPORTANT NOTE ON DATA

The definition of each variable and the data format are very important. Data for the NPHR modelling tool reflect the number of people in various educational tracks or job categories. If data that include other categories or exclude some of the population are used, the model may produce misleading results. The variables have been carefully defined to help avoid confusion. The format of the data is also critical to how the NPHR modelling tool makes calculations. When dealing with rates at which people enter education tracks or make career choices, data have been defined as fractions, expressed as decimals, of the population. For example, if 10% of a group retire, the rate will be expressed at 0.10. Entering data as a percentage will produce erroneous results or the model not functioning. The data available in the NPHR modelling tool is based mainly on the UK and the US studies and publications, the source for each worksheet is specified in the subsections below.

4.2. WORKING WITH THE DATA FILE

The data file opens to a Start worksheet. The Excel workbook data file is organized into separate worksheets, identified by the tabs across the bottom of the workbook.
The content of each worksheet is summarized on the Start worksheet and in Table 1. The two tabs, *Input* and *Input Data*, are worksheets that contain data linked from the other worksheets. In these two worksheets the data are formatted for import into the NPHR modelling tool. These worksheets are not to be modified by the users. Tabs formatted green are worksheets that contain data tables that need be updated with data for the country being represented in the model. Tabs shaded pink are worksheets containing static data that are provided for reference and can only be changed in special cases. If alternate data sets are desired to replace these data, new worksheets could be added to the file and the links in the *Input* and *Input Data* worksheets modified to connect to the new data.

In this section, each worksheet will be discussed in detail.

TABLE 1. WORKSHEETS IN THE NPHR WORKFORCE DATA SPREADSHEET

	Worksheet	Description
1.	Input	This page is imported by the NPHR modelling tool. It is formatted for import into the Stella Architect™ software. This page is a duplicate of the Input Data page with headers and notation removed
2.	Input Data	This page accumulates and arranges the data from the rest of the file. The page includes identification of the source spreadsheet for data for each variable

TABLE 1. WORKSHEETS IN THE NPHR WORKFORCE DATA SPREADSHEET

	Worksheet	Description
3.	Education	Contains tables of a country's educational statistics
4.	AgeDistribution	Contains data on the age of the workforce
5.	Attrition	Allows the user to define attrition rates
6.	National Workforce	Data on the current national workforce related to nuclear power
7.	Staffing	Data on the approach to staffing a nuclear power plant (NPP)
8.	Vendor Contract	Contains models for staffing the plant with assistance from the vendor
9.	HPC data	Construction workforce data derived from Hinkley Point C (HPC)
10.	Start up	Curves for staffing the operating organization in Phase 2 and Phase 3
11.	Outsourcing	Data on standard approaches to outsourcing parts of the operating workforce
12.	Regulatory	Data for the model of the regulatory body derived from the US Nuclear Regulatory Commission
13.	Decommissioning	Data for transition of the workforce for decommissioning the NPP

4.3. DATA SUMMARY TABS

This section covers the worksheets with tabs labelled Input and Input Data.

The *Input* and *Input Data* worksheets are used to format the data for import into the NPHR modelling tool. The *Input* worksheet is identical to the *Input Data* worksheet, except that labels, comments, and formatting have been removed. When data are imported into the NPHR modelling tool, it is the *Input* worksheet that the software reads, and not having comments and other extraneous information eliminates the risk of import errors. The *Input Data* worksheet contains links to the worksheets in the rest of the file, collecting and arranging the data desired for import. In the rest of the workbook the user can select between data sets and the *Input Data* worksheet includes in columns R and S descriptions for the choices made and which worksheet the source data are located.

4.4. TABS WITH USER DATA THAT MAY BE UPDATED

This section covers the worksheets with tabs labelled *Education*, *AgeDistribution*, *Attrition*, *National Workforce*, *Construction*, and *Staffin*g.

The worksheets with tabs shaded green contain data that the user needs to collect to reflect their nuclear power programme. These worksheets have common formatting schemes.

At the top of each worksheet is an area outlined in grey. This is the formatted data that is linked to the *Input Data* page. There are no changes to be made within this box.

Next to the grey box are cells shaded yellow. These cells are used to select between data sets that are located on the page. Next to the yellow cell is a list of available data sets to choose between.

Below the grey box are multiple data sets. These data sets include reference cases collected by the IAEA. Additional data sets are, on some worksheets, derived from the reference data by combining with country-specific factors. These cases may be used as estimates when actual data are not available. Other data sets are set up for the user to collect actual data for their country. It is recognized that data collected by the user may not be in the format expected by the NPHR modelling tool. It is the users' responsibility to manipulate the data to ensure proper interpretation by the NPHR modelling tool. This may be done in the workbook, ensuring that the data summary at the top of the case is properly linked to the data.

Within the data sets there are cells highlighted blue. These are cells where the user enters their data. If the data collected do not fit the specific definition needed by the NPHR modelling tool, it is recommended that a new worksheet be added for the data set. The data needs to be manipulated on the new worksheet and final values linked or copied to the existing data worksheet.

4.4.1. Education

Figure 1 shows the top of the *Education* worksheet. In the grey box are the data that are linked to the *Input Data* worksheet. The data include factors for the population in general and educational factors for the three career tracks for skilled craft training, technician training, and higher education (university). the values in the grey box follow the data definitions given above. The values in the grey box are summary values that are linked to data sets in the lower section of the data sheet. Variables with multiple values across multiple columns are arrayed elements in the NPHR modelling tool.

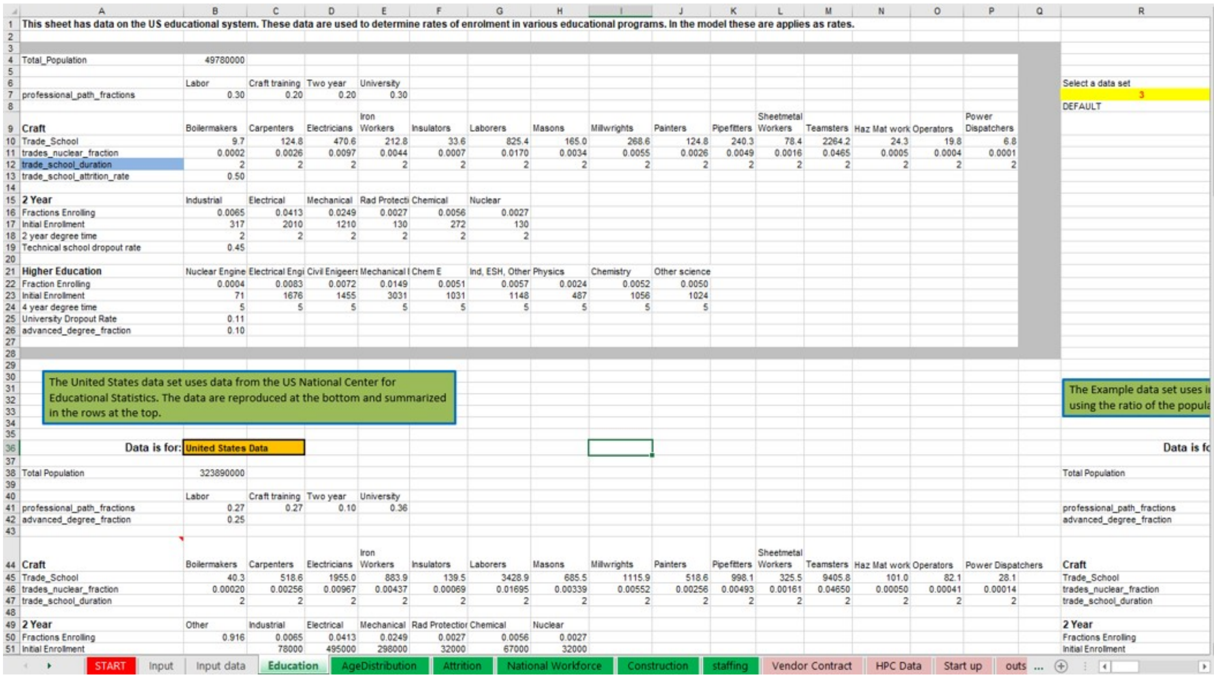

FIG. 1. The Education worksheet.

To the right of the grey box is a cell highlighted yellow and labelled *Select a data* set. Below the yellow cell is the title of the data set selected, and to the right is a list of four data sets available. Changing the number in the yellow cell selects a different data set.

Below row 28 are the data sets. Each data set has a description in a green box. The title of the data set is given in row 36. Rows 38–59 are formatted the same as the data in the grey box above. These rows summarize the data set and changing the selection in the yellow cell selects the data in these rows. It is necessary to enter data not in these rows, but instead only in the blue shaded cells.

The data sets for the *Education* tab are United States Data, Example, Default, and Custom. Each of these data sets are discussed below.

Education - United States Data

Starting in row 66, in columns A to D, are data for the United States educational system. This data set is included as an example of the data used in the NPHR modelling tool. The data source is included in the worksheet for reference. The data include numbers of students enrolled in various education tracks and statistics on national educational achievement.

Not all data are provided in the format specified by the definitions in Section 2. For example, the titles of educational tracks for two-year programmes do not match the skill categories commonly used in nuclear power. In column E, rows 81–87, is a mapping between the educational titles and nuclear technician skills. In addition, the data do not include attrition rates for the educational programmes. In column F are estimates of attrition based on the two-year education data and the four-year education data. These are examples of data analysis a user may have to do to adopt the available data to the NPHR modelling tool.

Education – Example

In Columns R to AH is a data set entitled Example. This data set derives a rough estimate for educational statistics by scaling the US data by the ratio of the population value entered in cell S69 to the population of the USA in cell B69. This is not expected to produce data that would be accurate for any country. Rather, it is included to illustrate how estimates may be done in the absence of specific data.

Education – Default

A data set labelled Default is given in Columns AI to AX. The default data set also scales the US educational data by the ratio of populations. In addition, the enrolment in educational programmes is calibrated using the population and the enrolment rates. Compared to the Example data set, the Default data set uses similar values but adds additional calibration to ensure consistency in the simulation.

Education – Custom

The Custom data set (Columns AZ to BP) is included as a template for data representing a specific case. The Custom data set may be used to represent a Member State as data are collected for their educational programme. It can also be used to develop a mix of default values and assumptions on specific programmes.

4.4.2. Age Distribution

The *AgeDistribution* worksheet contains histograms of the ages of the workforce and graduates from education programs. Ages are used in the model for calculations of workforce attrition and as an indicator of workforce sustainability. A workforce that is mostly younger may not have the experience that is desired for nuclear power while a workforce that is older may indicate a need for recruiting younger workers and an emphasis on knowledge transfer.

The *AgeDistribution* worksheet has three variables that are imported into the model, which are found in the grey box at the top of the worksheet. These data are age distributions for the workforce, graduates of four-year educational programmes, and graduates of two-year educational programmes. The age distributions are decimal fractions of each group in five-year age bands. The sum of values in each age distribution stays equal 1.

There are six distributions for the workforce defined in the worksheet. Entering a number in cell O8 chooses between the six which are listed in column T and U and defined below row 15.

Bar charts of the chosen distributions are shown to the right of Column U. For the age distributions for the graduates of educational programmes, there are two pre-defined distributions which appear below row 80.

The distribution choices are as following.

Age Distribution - Original US Data

This data set is derived from US industry data obtained in 2010. The original data are shown in rows 18 and 19 and formatted for use in the model in row 23.

Age Distribution - Revised US Data (2015)

This data set takes the Original US Data set and updates it to estimate the workforce ages in 2015. This was done by shifting the data in time and assuming attrition and recruitment to replace workers that leave.

Age Distribution – UK Data 2016

This data set was taken from a report on the United Kingdom workforce – National Nuclear Skills Strategic Plan – published in December 2016 [2].

Age Distribution – Uniform Age Distribution

This distribution assumes each age group is equally represented in the workforce. It is included as a test case to be used when nothing is known about ages in the workforce.

Age Distribution – Young Workforce

This distribution assumes that the workforce is made primarily of early career workers with fewer older workers. It is included as a test case.

Age Distribution – User Defined

The User Defined data set is included for the user to make assumptions about their workforce or to include data for their country. This distribution is set to match the uniform distribution. To modify this distribution the user may enter decimal fractions of the workforce that fall in each age band, ensuring that the sum of values over all age groups equals one.

Age distributions for graduates entering the workforce

For each age distribution for graduates of educational programmes, there are two pre-defined distributions which appear below row 80. One age distribution is an assumption about the ages at which people complete higher education, mostly in their early 20's. For each factor there is a User Defined distribution which the user can enter assumptions. The sum of the fractions stays equal to one.

4.4.3. Attrition

The *Attrition* worksheet contains data on how workers leave the workforce due to changing jobs, termination from an organization, retirement, or other reasons. The model uses two attrition factors, ***general attrition rate*** which applies to all workers and ***nuclear workforce attrition rate*** which applies to workers in the nuclear organizations. The reasons workers leave an organization or the workforce vary with age. Retirement becomes a larger reason for older workers, while job changes are more common for younger workers. Because of this, the attrition rates are defined by age bands.

In the grey box are the data for the two attrition factors in the model. To the right of the grey box are yellow selection cells for which attrition model is desired. There is a data set called

Assumed Attrition Rates and a data set called User Attrition Rates. These are defined below row 13 and displayed in the charts on the right side of the page.

Attrition rate is defined as the fraction of people in the age group that leave the group or organization per year. By this definition, if there were 100 people of age 40–44 and a corresponding attrition rate of 0.01, then 1 person would be removed from the organization each year.

Attrition – Assumed Attrition Rates

The Assumed Attrition Rates data set includes factors for attrition because of each of the following mechanisms:

- Job change – the worker chooses to leave the organization to pursue other work in the nuclear industry;
- Termination – the worker is removed from the organization because of performance, conduct, or suitability issues;
- Retirement – the worker reaches an age at which they retire and are no longer part of the workforce;
- Career change – the worker leaves the nuclear industry to pursue non-nuclear related employment.

Each factor is defined by age group. The overall attrition rate is the sum of each of these factors. An example calculation is given below row 36.

Attrition – User Attrition Rates

The User Attrition Rates data set is included for the user to develop their own model of attrition based on knowledge of workforce norms in their country. The data set is configured with the same four attrition mechanisms as above plus two additional factors. These additional factors can be used to include factors unique to how careers progress in the workforce specific to a country.

4.4.4. National Workforce

The *National Workforce* worksheet contains data describing the workforce at the start of the simulation in the NPHR modelling tool. The objective of this worksheet is to establish the number of workers in each field of interest to the nuclear power programme. The data are summarized in the grey box at the top of the worksheet. There are three data sets in the worksheet that may be selected by changing the number in cell R4, highlighted yellow.

The three data sets are:

- US Data – data for the US nuclear industry;
- Scaled data - data for the US nuclear industry scaled by the ratio of national population to the population of the US;
- Country data – a data table prepared for the user to enter data for their country.

The US data are taken from the US Bureau of Labor Statistics (BLS). The BLS data have a summary table for nuclear power generation which provides the figures on employment in the nuclear industry. Other BLS tables provide the national data on overall employment by occupation. The authors of the NPHR modelling tool assigned a skill level to each occupation, identifying them as management, professional (4-year degree holders), technicians (2-year degree holders), skilled craftsmen, or semi-skilled workers. A copy of the BLS data appear in columns T to AA. These data are adjusted and formatted below row 36, where the overall workers by occupation are divided into the workforce pools used in the NPHR modelling tool. Additional factors are added for how many workers might gain experience in nuclear power skills per year and the decimal fraction of workers in each occupation that might be qualified to work in nuclear power.

4.4.5. Construction

The *Construction* worksheet contains data related to the construction phase of an NPP. The data available are from the HPC NPP and from a study made by the US Department of Energy. The original HPC data are in a worksheet called *HPC Data* and the relevant factors are copied to the *Construction* worksheet. This tab for *HPC Data* is shaded pink and no data can be changed. The data include overall numbers of workers in the HPC project divided into project management and engineering, civil construction, and mechanical construction. These are converted to annual hiring numbers and copied to the *Construction* worksheet. The data from the US Department of Energy study are shown in the *Construction* worksheet below row 37 and give the fraction of workers by skill in construction of an NPP. The number of workers of each skill hired by year are calculated and summarized in the table in the grey box. Additional factors include the division of each skill into civil and mechanical phases of construction, which is specified in the variables ***craft_mechanical*** and ***craft_civil***. These factors are estimates by the authors.

A significant decision by the NPP project is the approach to contracting with the vendor for construction of the NPP. The contract may specify how the vendor is expected to source workers for construction from the host country workforce. The four variables related to contract model specify different fractions by skill area. The user may change these to examine different approaches.

4.4.6. Staffing

The *Staffing* worksheet contains data related to the staffing of the operating organization. The operating organization may be viewed as 7 process areas: operate the plant, equipment reliability, materials and services, support services and training, work management, configuration management, and loss prevention. More information on that issue can be found in the publication Workforce Planning for New Nuclear Power Programmes, IAEA Nuclear Energy Series No. NG-T-3.10, hereafter referred as ‘Workforce Planning’, [3]. In the model of staffing, the operating organization specifies the training background and skill level of workers for each process area. The data set allows for two selections, one that sets the fractions of the operating workforce by skill level and a second that divides the workforce for each process area across skill areas.

The variable ***skill area fractions*** divides the operating workforce by skill level: managerial, professional, technician, skilled craft, and semi-skilled. The worksheet has two choices for skill area fractions, UK data and US data from BLS. The UK data is based on analysis on the UK workforce [2]. The US Data is derived from the BLS data on the *National Workforce* worksheet.

The staffing model consists of matrices of how each process area is populated by education and training. The data is organized as a matrix for each of the skill levels, professional, technician, and craft. The spreadsheet has four data sets to choose from:

- Uniform Distributions – each education or skill track is equally represented and the same for each process area;
- Workforce Fractions – each education or skill track is represented by the fractions in the BLS data, and the same fractions are specified for each process area;
- Custom I – each education or skill track is represented by degrees related to the work content of the process area;
- Custom II – by default the same as Custom I but may be used to develop a new case.

The *Staffing* worksheet also includes the factor ***second unit operation factor***. This factor is used to scale the workforce to account for efficiencies from operating multi-unit NPPs. Analysis of the example staffing in the Workforce Planning document [3] suggest that operating two units required approximately 47% additional staff as compared to a single-unit plant. For the purposes of the model, a four-unit NPP is treated as two two-unit NPPs.

4.5. WORKSHEETS WITH STATIC DATA

This section covers the worksheets with tabs labelled *Vendor Contract*, *HPC Data*, *Start Up*, *Outsourcing*, *Regulatory*, and *Decommissioning*.
The data file has 6 worksheets with tabs that are coloured red. These worksheets have static data that the user does not need to change. The data are included in the file so that the user may examine the data to gain understanding of the model.

4.5.1. Vendor Contract

An option for operation of the NPP is to contract with the vendor for various levels of support. Some generalized approaches to operating contract are outlined in the Table 2:

TABLE 2. VENDOR CONTRACTS

No.	Type of Contract	Description
1	BOO (Build-Own-Operate)	The vendor is responsible for operating the NPP
2	BOOT (Build-Own-Operate-Transfer)	The vendor is responsible for operating the NPP for a fixed period after which the domestic operating organization is responsible
3	Turnkey	The domestic operating organization is responsible for operating the NPP
4	User 1	The user defines the level of support from the vendor
5	User 2	The user defines the level of support from the vendor

The *Vendor Contract* worksheet specifies the portion of each workforce function that is the responsibility of the vendor for each contracting approach. These portions, expressed as percentages, appear in columns C through G. Two places are provided for the user to create approaches they might consider, called User 1 and User 2. The percentages are converted to number of workers using the data in the staffing worksheet, then condensed into decimal fractions by process area. These decimal fractions appear in the grey box and are linked to the *Input Data* worksheet. All five options are imported into the NPHR modelling tool and may be selected when the model runs.

Two additional factors are needed to specify the BOO option. These are the time between plant startup and the start of handoff to the domestic staff and the number of years over which the transition occurs. The data file provides default values that can then be changed while running the model.

4.5.2. HPC Data

The *HPC Data* worksheet is described in the section on the *Construction* worksheet.

4.5.3. Start Up

The *Start Up* worksheet contains data on how the operating organization is developed during the construction phase. Three versions of the startup curve appear in various references. In the *Start Up* worksheet these are used to determine hiring rates for the operating staff by skill level. The data are further divided into periods corresponding to licensing the plant and construction of the plant. Since these periods may be varied in the model, the staffing data during startup specify the fractions of workers hired during each period which is then converted to a hiring rate using the model settings for licence review time and construction time. The model currently defaults to using the Nuclear Power Institute version of the startup curve.

4.5.4. Outsourcing

Outsourcing is the approach to workforce management that has staff at the NPP being provided by an outside entity through use of a contract. There are multiple approaches that are found in references. For strategic planning for the national workforce, the important consideration is if the workers provided on contract are drawn from the national workforce or from a foreign contractor. If they are domestic workers, they are drawn from the same workforce pools and education system as staff employed directly by the operating organization.

Four approaches are included plus a space for the user to specify an approach. All options are imported into the model and can be selected while running it.

4.5.5. Regulatory

The *Regulatory* worksheet specifies factors related to the staffing of the regulatory body. These data are based on the US Nuclear Regulatory Commission. Currently, the model does not provide any options for changing the factors for the regulatory body.

4.5.6. Decommissioning

The NPHR modelling tool includes staffing of a decommissioning organization. This feature is still under development and is only useful if the user is interested in modelling to the end of plant life. For most users, strategic planning only includes startup of the NPP. The data are based on the Decommissioning of Nuclear Facilities: Training and Human Resource Considerations, IAEA Nuclear Energy Series No. NG-T-2.3 [4].

5. WORKING IN NPHR MODELLING TOOL

This section covers interacting with the NPHR modelling tool in a run-time mode by means of the model interface. The model can be opened in two ways:

- Start the Stella Architect software. In the top menu, select File, Open, and navigate to the NPHR folder. Select the file NPHR3.0.stmx file;
- Alternatively, the tool can be started from a file directory by selecting NPHR3.0.stmx.

5.1. INTRODUCTION PAGE

Stella Architect™ opens the programme in a modelling window. The lower part of the screen shows three model elements, called modules, that are labelled *Nuclear Power Plants*, *Workforce*, and *Program*. Double clicking on these modules will open sections of the model. The module *Nuclear Power Plants* contains a representation of the life cycle of an NPP. The module *Workforce* contains a representation of the national workforce that supports the nuclear power programme. The module *Program* contains a representation of the early stages of a nuclear power programme but is not currently used in the human resource analysis. Technical information on the NPHR modelling tool can be found in the appendices to this document.

On the Stella Architect™ menu bar, the control on the furthest right is shaped like a movie screen and is a link to the interface for the model. In Stella Architect™, the interface is an interactive environment that includes model controls, the ability to change variables in the model, and formatted output. Clicking on **Open Interface Window** opens a new window that is used to develop Stella Architect™ model interfaces and shows the NPHR interface. In this window, the interface is in development mode and changes can be made to the interface to add custom model controls and output. However, in this window the interactive controls for the interface are not active.

Clicking on the Presentation Mode control opens the interface in interactive mode on the NPHR welcome page, as shown in Fig. 2. The model controls are now active and can be adjusted to run the model.

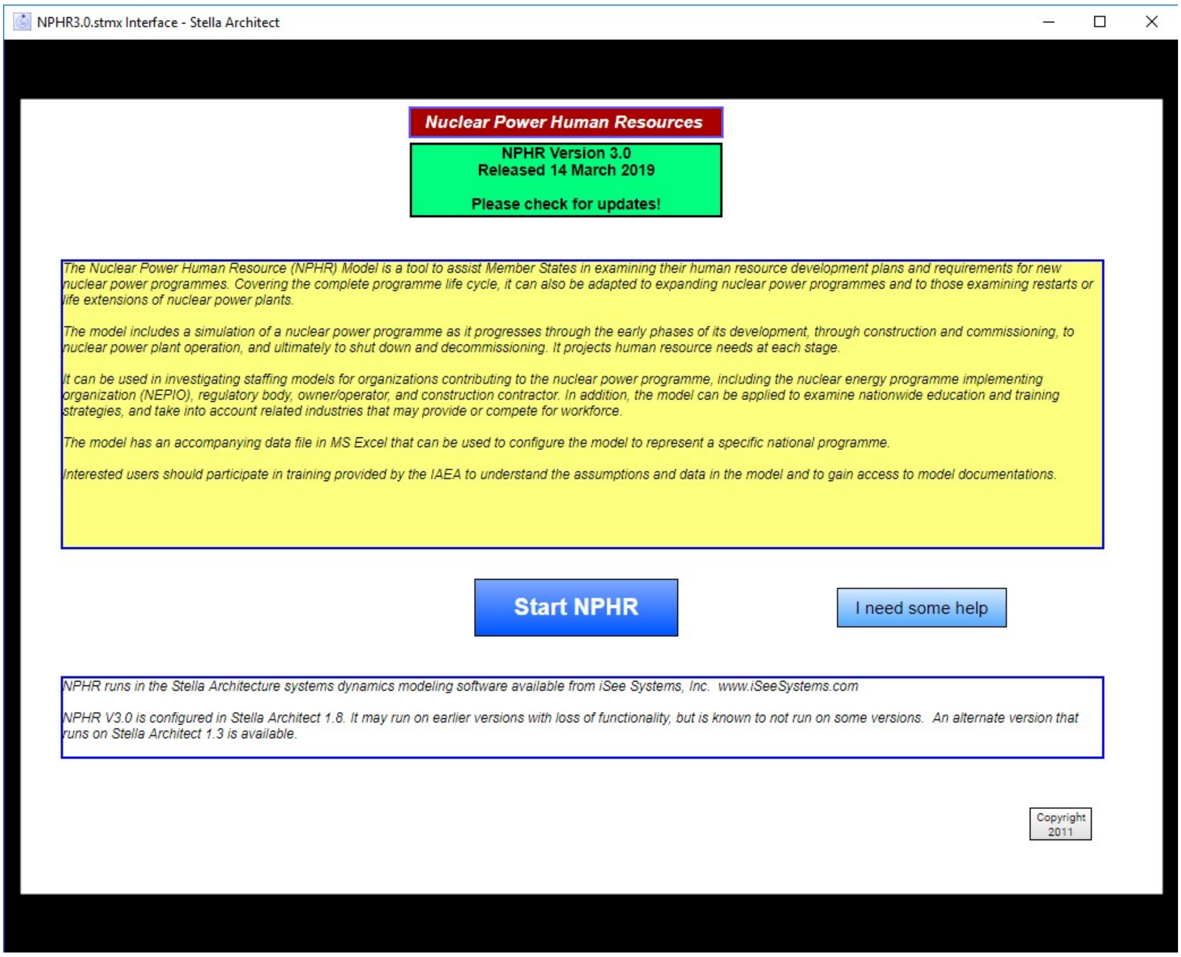

FIG.2. NPHR modelling tool Introduction Page.

5.2. NPHR MODELLING TOOL INTERFACE

Once the interface has been opened, the model is in an interactive mode. The interface consists of multiple pages which contain model controls, settings, and output. Navigation between pages is done by use of controls called buttons. Data and settings may be adjusted on multiple pages. The model may be run at any time from any page, but no results can be interpreted as final until all settings have been reviewed and adjusted.

5.2.1. I Need Some Help Page

Below the welcome message are two navigation buttons labelled **Start NPHR** and **I Need Some Help**. Clicking **I Need Some Help** navigates to the page, which has a guide to the controls that will be found in the model. Important features of the interface for the NPHR modelling tool include:

- Simulation controls – located on the upper left are start, stop, pause, and speed control;
- Navigation – located on the upper right are buttons to navigate to different pages;
- Model Settings – in the centre of the page are examples of the various model input mechanisms and control features.

Selecting the **Help** button on any page of the interface returns to this screen.
Selecting **Done** returns to the welcome screen.

5.2.2. Nuclear Power Page

Selecting **Start NPHR** navigates to the *Nuclear Power* page, shown in Fig. 3. This page allows the user to set the plan for introducing nuclear power. On the left side of the page are tables that show the years during which each unit of two NPPs are scheduled to begin operation. The user may change any of these dates by clicking on the box and entering a new date. Entering a date beyond the simulation period such as 2200 means the unit will not be built.

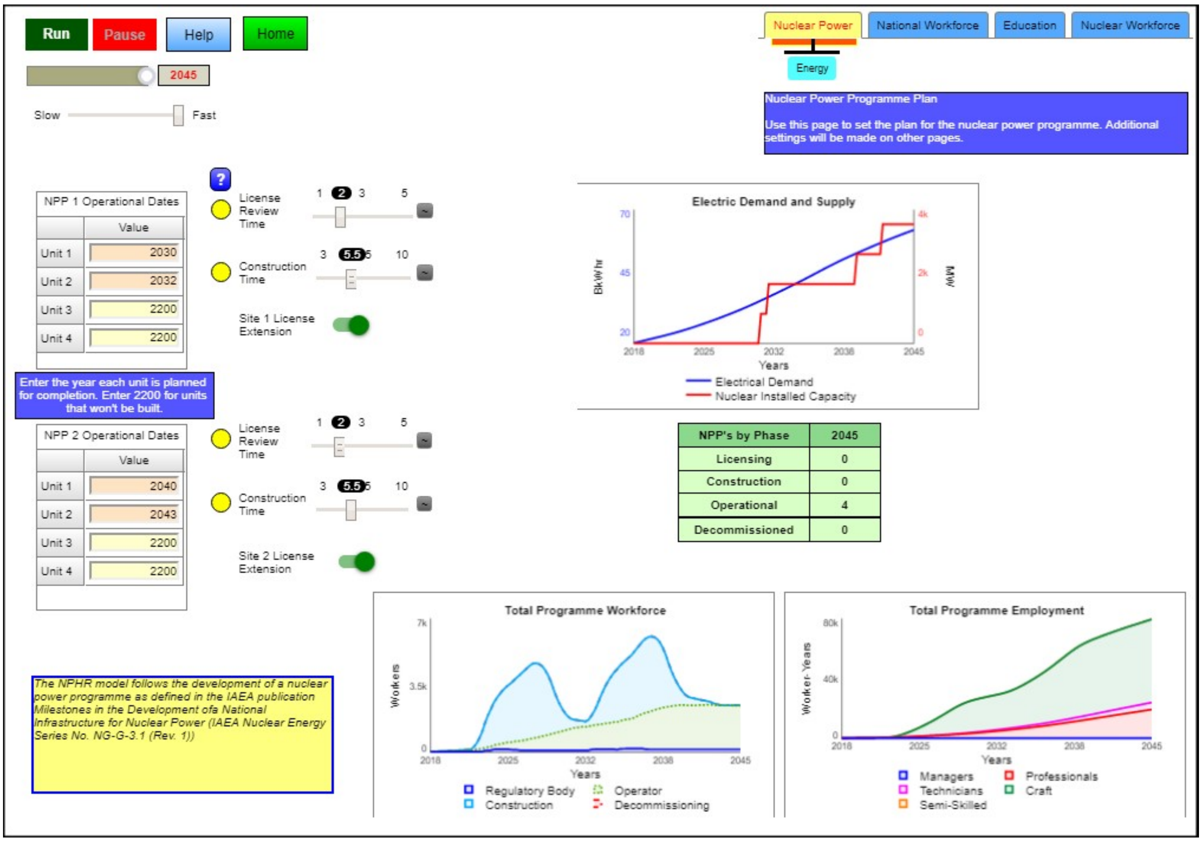

FIG. 3. The Nuclear Power Page.

To the right of the Operational Dates tables are controls to set assumptions for the length of licence review and length of construction for each NPP. The controls can be dragged to select a longer or shorter assumption. The circular indictors next to each control will indicate green if the setting is equal to or longer than the data from previous nuclear power projects worldwide, yellow if the setting is slightly shorter, and red if the setting is much shorter.

Below these controls is a switch to model each NPP having a life extension beyond their initial 40-year design life. For most users, the simulation is not run to the end of the NPP design life and these controls do not affect the model results.

To the right of the controls are three high-level summary charts. The top chart shows the national electrical demand (BkWhr, left axis) and the installed nuclear capacity (MW, Right Axis). Note that the national energy demand relies on settings described in the next section. The status of the nuclear power units is shown on the table in the centre of the page.

Two charts on the bottom of the page summarize the workforce for the nuclear power programme. The chart on the left shows the total number of workers by year in each of the main organizations in the programme, the regulatory body, the operating organization, construction, and decommissioning. These same data are shown by skill level in the chart to the right expressed as cumulative worker-years in five skill levels, managers, semi-skilled, skilled craft, technicians, and professionals. The manager and semi-skilled categories are not currently populated with data. These two charts are summaries of data that are shown in greater detail in other parts of the interface.

Energy

In the navigation controls at the upper right, below *Nuclear Power* is a button labelled **Energy**. Selecting this button opens a page displaying the national energy demand. On the left side of the page, there is a box for entering the total electrical demand at the start of the simulation. Below the box is an interactive graph for setting the energy growth rate for energy demand over time. Clicking on the graph opens the graph in a small window. Clicking on the chart in this window changes the growth rate curve over time. Close this window by clicking **Cancel** or **Ok**.

In the centre of the page is a control entitled **Expected NPP Capacity Factor**. This factor represents the fraction of time the NPP is expected to be generating power.

To the right of the page are charts showing energy generation. The top chart is a duplicate of the demand and supply chart on the *Nuclear Power* page, along with the summary status table of the NPPs. The bottom chart shows the percentage of electricity demand that is provided by nuclear power.

The settings on the *Energy* sub-page are used to calculate the power from NPPs over time. These settings do not have any effect on the human resources calculations.

5.2.3. National Workforce Page

The national workforce includes workers in other roles that may have the skills and experience that are needed for a nuclear power programme. A comprehensive human resource development strategy will take into consideration these roles as both competition for workers and as a potential source of workers. It is challenging to quantify the number of workers in various parts of the workforce, and to evaluate how many might have skills and experience appropriate for nuclear power.

Selecting the *National Workforce* in the navigation panel opens a summary page for the national skills related to nuclear power, shown in Fig. 4. The two charts at the top show summaries of workers in the operating organization, regulatory body, technical support organizations (TSOs), and related industry with four-year degrees in sciences and engineering and two-year training for technician skills.

FIG. 4. The National Workforce Page.

A major challenge in understanding the national workforce is quantifying the workforce outside the key nuclear power organizations which are summarized in the model as TSOs and related industry. TSOs are independent organizations that support the operating organization and regulatory body by providing technical expertise and may also provide service to organizations other than the nuclear power programme. There are no specific guides for the size or organization of the national TSOs. In the early phases of a nuclear power programme, human resource development planning can consist of determining if the strategies for the operating organization and regulatory body will use TSOs extensively or sparingly. The sliding controls below the charts and to the left are used to set the ratio of workers in TSOs to workers in the operating organization and to workers in the regulatory body.

Related industry includes other organizations, companies, and institutions that employ workers with similar skills to those needed for nuclear power. Related industry may include other power generation facilities, installations that require control of hazardous material, industries that require high risk or quality control, and others. The number of workers in related industry is set in the data file. The key variable in the model is the expected annual growth in these roles. This is set in the Growth in Related Industry setting below the right-hand chart.

The model has two tables at the bottom of the page to evaluate TSOs and related industry as potential sources of experienced workers. The values in these tables are the decimal fraction of workers in TSOs and related industry that might have the qualifications and experience to be considered for the job functions in the table. These decimal fractions can be set to values between 0 (no workers with skills and experience for nuclear power) to 1 (all workers have skills and experience relevant to nuclear power). Entering a higher number in the tables will allow more workers from TSOs and related industry to be considered for positions in the operating organization and regulatory body.

In the navigation panel, below the **National Workforce** button, are three buttons that open sub-pages *Craft*, *Technician*, and *Professional*. These three buttons contain model results for examining the workforce for each skill level.

The *Craft* sub-page shows model results for skilled craft workers. On the left, centre of the page is a list of the 15 craft occupations included in the model. Entering the number corresponding to a craft skill in the **Select Craft** box and running the model will change the output to that craft skill. The upper chart shows the percentage of the national workforce with the selected skill that is required for the nuclear programme. Requiring a significant fraction of the national workforce suggests availability of workers with that skill may present a risk to the nuclear power programme. The lower chart shows the national workers with the selected skill by experience level. Selecting **Include Only Qualified Workforce** restricts the display to include only the pool of workers that might be qualified to work in nuclear power.

The *Technician* sub-page shows model results for the six technician skills indicated in the list on the left side of the page. The functionality of this sub-page is the same as the functionality of the *Craft* sub-page described above.

The *Professional* sub-page shows model results for the nine engineering and science disciplines indicated in the list on the left side of the page. The functionality of this page is the same as the functionality of the *Craft* sub-page described above.

5.2.4. Education Page

The model estimates the number of people entering the workforce in the fields of study of interest to the nuclear power programme. The estimate starts from the number of secondary education graduates and tracks them through formal education to entering the workforce. In this process students choose career paths which may or may not be useful in nuclear power and some leave the educational tracks they started. National programmes may incentivize students to pursue educational tracks related to nuclear power.

The *Education* summary page covers the national education system for nuclear related fields, as shown in Fig. 5. The centre chart shows the national population and the annual graduates completing secondary education. The starting population is set in the data file. How the population changes over time is determined by the population growth rate, which can be changed using the graphical input at the top left of the page. On the top right side of the page is a graphical input for secondary graduation rate. This allows the model to reflect national education initiatives to increase the number of students completing secondary education. The bottom left chart shows model results for enrolment in the fields related to nuclear power at the skilled craft, technician, and professional levels. The chart on the lower right shows the number of workers receiving initial training for the nuclear power programme. The sliding control in the centre is used to adjust the rate at which new hires fail to complete initial training.

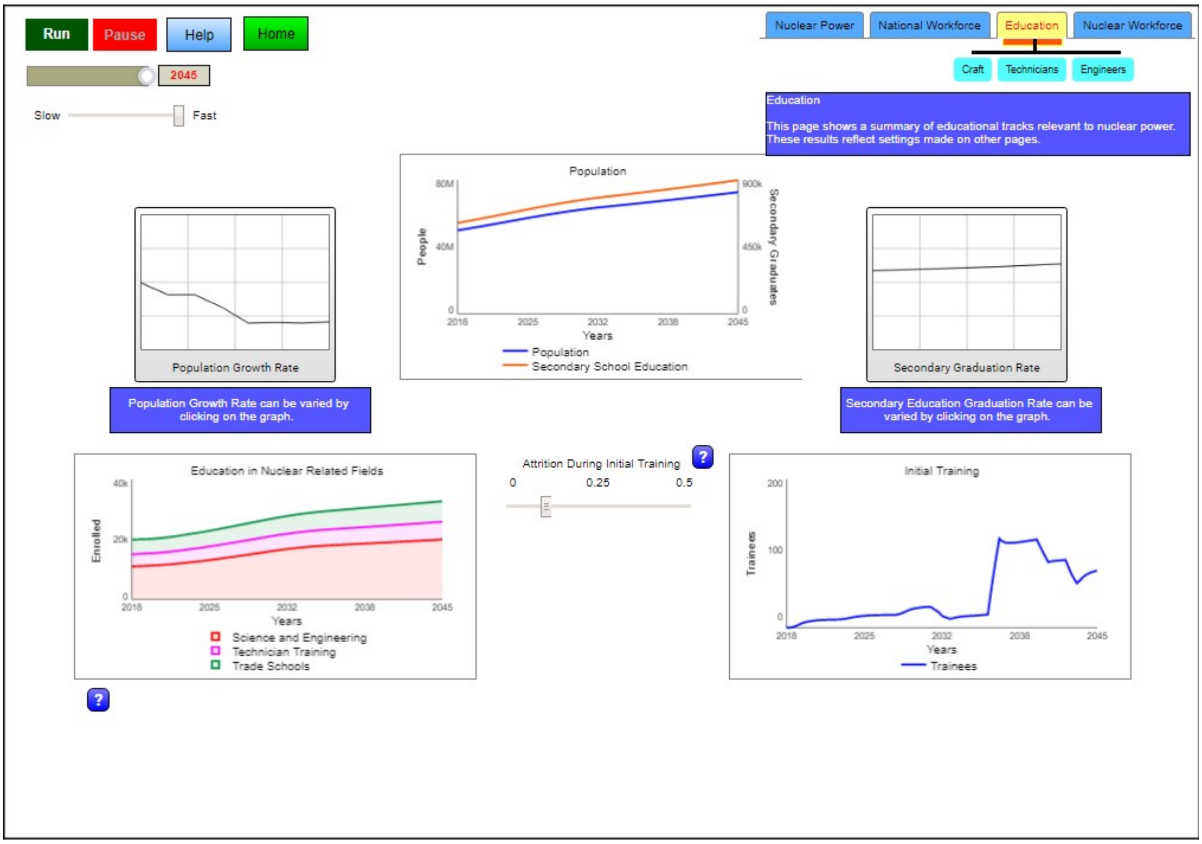

FIG. 5. The Education Page.

Under the *Education* page are three sub-pages labelled *Craft*, *Technician*, and *Engineering*.

Selecting the *Craft* summary page navigates to career training for skilled craft workers. While the overall model includes 15 skilled craft careers, on the *Craft* sub-page 8 careers that are typically underrepresented have been highlighted. The blue highlighted box near the centre of the page identifies these 8 skills with the initial enrolment in training for those career paths. The interface can be modified to show additional skills of interest.

The charts on the right side of the page show the number of students enrolled in training programmes for these skills. The upper graph is focused on skills for construction, although some of these skills may also be needed for operations. The lower chart is focused on craft skills specific to NPP operations. The chart on the upper left shows the total number of students entering craft training programmes along with the graduation rate.

The purpose of modelling is to represent the effect of initiatives to change the enrolment over time. The model controls in the centre of the page allow changing several factors that can be adjusted. One initiative might include incentives for training in craft skills, which would be expected to increase enrolment in all craft training. The top control labelled **Craft Training Initiative** can be used to set the expected percentage increase in enrolment for such incentives. At the same time, attracting more students into training programmes may also increase attrition rates. This can be explored by adjusting the **Craft Training Program Attrition Rate** control.

Alternatively, there may be an interest in expanding a specific field of study or starting a new training programme for a skill. In the centre of the page is a table with four navigation tabs at the top. The tab labelled **Growth** shows a table of a targeted increase in trainees for each field. For example, entering 10 in this table will have the model increase the annual enrolment in that field by 10 students. The tabs **Start** and **Finish** set the years over which the increase will occur. Finally, **Duration** is the length of time a student takes to complete their studies.

The *Technician* sub-page covers training programmes for technicians. This sub-page highlights six fields of study at the technician level. The functionality of this page is the same as the functionality of the *Craft* page described above.

Selecting the *Engineers* mode navigates to a page on educational programmes for Engineers and scientists. This page highlights six fields of study in engineering disciplines and three science disciplines. The functionality of this page is the same as the functionality of the *Craft* page described above.

5.2.5. Nuclear Workforce Page

The nuclear workforce part of the NPHR modelling tool shows the workforce for the main organizations of the nuclear power programme, the Nuclear Energy Programme Implementing Organization, construction workforce, the operating organization, and the regulatory body. The model results depend on the settings for the nuclear power programmes and the results of the analysis of the national workforce and education system.

The *Nuclear Workforce* page shows a summary of the workforce for the four main organization in the nuclear power programme expressed as total workforce levels by organization shown in Fig. 6. For the operating organization and the construction workforce, key strategic decisions affect the number of domestic workforce versus vendor-provided workforce. This is indicated in the charts for those organizations.

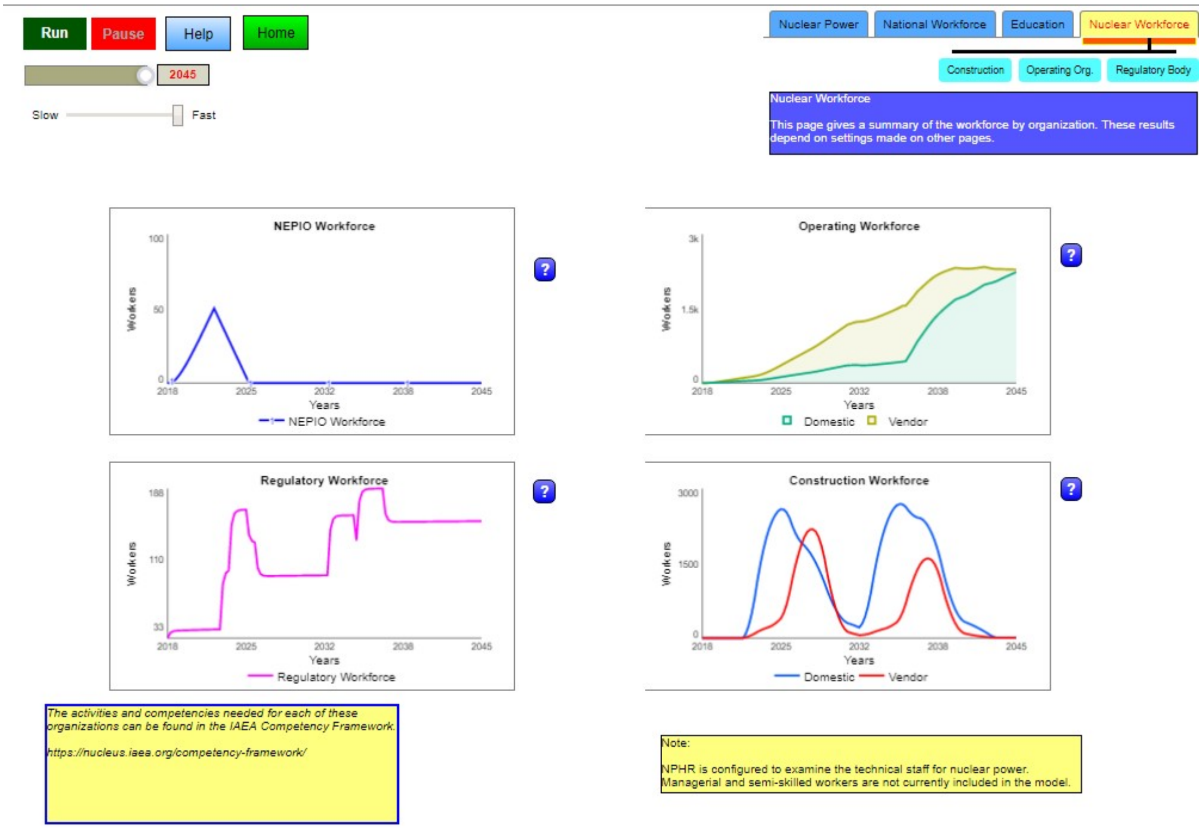

FIG. 6. The Nuclear Workforce Page.

Selecting the *Construction* sub-page navigates to a page with settings for the construction phase of the programme. This page allows changing the conditions of the EPC contract and adjusting assumptions about the workforce size. The NPP owner/operator may specify in the EPC contract the level of workforce the vendor is expected to recruit from the domestic workforce versus outside the country. In addition, the total workforce required for construction of a plant may vary widely between construction projects and in the planning stages.

At the top left side of the page are selection controls marked **EPC Vendor Contract**. These controls adjust the strategy for the construction workforce and consist of fractions of workers by each skill coming from the domestic workforce versus the vendor. There is a selection for each NPP site, meaning each NPP site may employ a different strategy for construction workforce. The model includes four contract approaches. The top three choices — maximum vendor, medium vendor, and minimum vendor — are built-in choices with varied levels of staffing coming from outside the country. The fourth option, user defined, allows the user to set the level of vendor-provided workers. The fractions for each of these strategies may be changed in the data file on the *Vendor Contract* worksheet (See Section 4.5.1). When the model is run the bar chart below the controls shows the fractions for each skill provided by the EPC vendor for site 1. The chart on the bottom left shows the overall percentage of construction workforce coming from the national workforce.

On the top right of the page are two slider controls for adjusting the overall size of the construction workforce. The data built into the model is based on planned staffing for the HPC project in the UK. The two sliders labelled **Construction Workforce Size** allow adjusting the construction workforce for each NPP site to be larger or smaller than the workforce for HPC. This allows investigation of impacts to the workforce if the projects being modelled are assumed to be more efficient or less efficient than HPC and allows the workforce planning analysis to be conservative in the estimation of workforce demand.

In the centre of the page are two charts showing the construction workforce. The upper chart divides the workforce in terms of civil construction skills versus mechanical skills. The lower chart shows the division between domestic workers versus vendor-supplied workers.

On the bottom right of the page is a chart to examine specific skills. The chart shows the percentage of a national craft that is required for executing the nuclear power programme. The data displayed corresponds to the number entered in the **Select Craft** box. Not all people in the workforce trained in a skill are qualified to work in nuclear power. The selector labelled **Include Only Qualified Workers** is used to reduce the assumption on how many workers are to be considered in the calculation of the percentage of the national workforce.

Nuclear Workforce – Operating Organization

Selecting the *Operating Organization* sub-page navigates to a page showing the workforce for the operating organization. The model of the operating organization in the NPHR modelling tool is based on the staffing example for a pressurized water reactor shown in Appendix I of the Workforce Planning document [3].

The key decision affecting the staffing size is the contracting arrangement made with the vendor for support of operations. In the centre, near the top of the page, are selections for contracting approaches (as shown in Table 2).

The selection of **Vendor Contract** control determines the workforce that is drawn from domestic sources versus supplied by the vendor from their workforce. For BOOT contracts, the duration in years that the vendor is responsible and how long the transfer will take are additional controls to the right of the contract selectors. The User 1 and User 2 options may be specified in the data file to allow the user to specify the division of workforce.

On the upper left of the page are controls to specify the assumed size of the operating organization relative to the reference data in the publication Managing Human Resources in the Field of Nuclear Energy, IAEA Nuclear Energy Series No. NG-G-2.1 [5]. The desired size of the operating organization may be different from the reference for multiple reasons, for example:

- Assumed efficiency of operations;
- Economic competitiveness;
- Use of NPP operations to develop experienced workforce;
- Improvements in operation from experience.

Adjusting the controls on **Operational Staff Size** will change the workforce requirement for each NPP.

The results of the operations workforce model are summarized in four charts. The top left chart shows the year-to-year workforce by skill level. The chart on the top right shows the operating workforce as vendor or domestic workforce. On the bottom right is the vendor and domestic workforce expressed as cumulative worker-years.

Sustainability of the workforce and knowledge management are key characteristics of workforce management. The chart on the bottom left shows the age distribution of the workforce. This is a basic indicator of the experience level of the workforce at a given time and the risk of losing workforce due to retirements.

Nuclear Workforce – Operating Organization - Recruiting

It may be desired to assemble the operating organization with a mix of senior, experienced leaders, workers with various levels of domain expertise, experience in a nuclear environment, and entry level workers. A healthy organization will seek to maintain a balance of diverse backgrounds. The NPHR modelling tool includes a representation of the recruiting strategy for the operating organization.

When the *Operating Organization* page is active, a button labelled **Recruiting** is visible in the navigation panel. Selecting the **Recruiting** button navigates to a page that allows setting a strategy for recruiting workers for the operating organization. On the left of the page are three dialog boxes, one for each skill level. In each dialog box the user may specify the fraction (0 (none) up to 1 (all)) of each skill level intended to be recruited from each of four workforce pools presented in the Table 3.

TABLE 3. WORKFORCE POOL OPTIONS

No.	Workforce pool	Description
1	TSO	Workers that have technical knowledge of nuclear technology
2	Related Industry	Workers that have domain knowledge but not necessarily in a nuclear environment
3	NP Qualified	Workers that have the appropriate formal education but not necessarily work experience
4	NP Experienced	Workers with the appropriate qualification and experience in nuclear power

The model includes a hierarchy for hiring; if adequate numbers of workers are not available in a pool, the model recruits from a less experienced workforce pool. The chart to the right of each strategy dialog box shows the success of the national workforce in meeting the desired strategy. If the national supply of workers in each category is maintained at an adequate level to meet the demand, the charts will indicate a constant hiring fraction. If a pool becomes depleted, the curves will show a change indicating that fewer are recruited from one pool and are instead drawn from a different pool.

Caution: in some cases, the demand becomes small and the ratio of hired to demand becomes very large. To prevent computational failures when the demand becomes small the recruiting fraction defaults to 0.

Nuclear Workforce – Regulatory Body

Selecting the *Regulatory Body* sub-page navigates to a page showing the workforce for the regulatory body. In the NPHR modelling tool the regulatory body is based on data from the US Nuclear Regulatory Commission. The upper chart shows the workforce demand for the regulatory body. The lower graph shows the age distribution for the regulatory body.

APPENDIX I.
DATA DEFINITIONS

Table 4 contains definitions for the data used in the NPHR modelling tool.

TABLE 4. NPHR MODELLING TOOL DATA DEFINITIONS

No	Variable	Definition
1.	Total_Population	Total population for the country
2.	trade_school_attrition_rate	Decimal fraction of those enrolled in craft training programmes that leave the programme in a year without completion
3.	craft_attrition_rate	Decimal fraction of craft workers that leave their field annually for job change, retirement, or other reason
4.	craft_construction_attrition_rate	Decimal fraction of craft workers hired to construct the NPP that leave employment annually for job change, retirement, or other reason
5.	craft_training_attrition_rate	Decimal fraction of those craft new hires that do not complete their initial training
6.	tech_dropout_rate	Decimal fraction of students studying the technician areas needed by the nuclear power programme that terminate their studies for any reason
7.	tech_training_attrition_rate	Decimal fraction of workers with technician training hired to work in the operating organization that leave employment during their initial training
8.	university_dropout_rate	Decimal fraction of students studying the professional areas needed by the nuclear power programme that terminate their studies for any reason
9.	engineer_training_attrition_rate	Decimal fraction of workers with professional degrees hired to work in the operating organization that leave employment during their initial training
10.	advanced_degree_fraction	Decimal fraction of those that complete a four-year degree that continue for an advanced degree (MS and Ph.D.)
11.	BOOT_transition_time	Number of years for operations to transition from vendor to a domestic organization
12.	BOOT_delay	Number of years following NPP startup that operations begins to transition from the vendor to a domestic organization
13.	professional_path_fractions	Decimal fractions of those completing secondary school that choose among the career paths: Labour - no further education

		Skilled craft – career training, apprenticeships, or on-the-job training Technicians - two-year degree programmes Professional - four-year degree programmes
14.	Trade_School	The number of students studying each craft skill at trade schools at the start of the simulation
15.	trades_nuclear_fraction	Decimal fraction of all students entering trade schools that are entering training for skills needed by the nuclear power programme
16.	Trade_school_duration	Number of years craft workers receive formal training before joining the workforce, by craft skill.
17.	site_1_craft_fraction_per_plant	Decimal fractions of craft workers in each craft skill employed in the construction of the NPP at site 1.
18.	site_2_craft_fraction_per_plant	Decimal fractions of craft workers in each craft skill employed in the construction of the NPP at site 2.
19.	craft_mechanical	Decimal fraction of each craft field that are employed in the installation of equipment during construction of the NPP. Craft civil and craft mechanical stay sum to 1 for each skill
20.	craft_civil	Decimal fraction of each craft field that are employed installing buildings, utilities, and other civil construction during construction of the NPP. Craft civil and craft mechanical stay sum to 1 for each skill
21.	Craft_Labor_Pool	The total number of workers in the country working in each craft skill not including the numbers in the defined work areas: excluding Related Industry, and Experienced Craft Labour
22.	Craft_in_Related_Industry	The total number of workers in each craft skill working in Related Industry
23.	Experienced_Craft_Labor	The total number of workers in each craft skill that have experience relevant to operation of an NPP. Do not include those in Related Industry
24.	craft_nuclear_qualification_rate	The decimal fraction of the national craft labour pool for each craft skill that could be qualified to work in construction or operation of an NPP
25.	craft_experience_rate	The number of craft workers each year that are sent to gain experience relevant to operation of an NPP
26.	contract_model_max	The decimal fraction of each craft skill for construction that is to be provided by the vendor for the max case
27.	contract_model_med	The decimal fraction of each craft skill for construction that is to be provided by the vendor for the med case

28.	contract_model_min	The decimal fraction of each craft skill for construction that is to be provided by the vendor for the min case
29.	contract_model_user	The decimal fraction of each craft skill for construction that is to be provided by the vendor for a case to be defined by the user
30.	process_area_craft_fractions[1,*]	Decimal fraction of workers in process area 1 that are trained in each craft skill.
31.	process_area_craft_fractions[2,*]	Decimal fraction of workers in process area 2 that are trained in each craft skill.
32.	process_area_craft_fractions[3,*]	Decimal fraction of workers in process area 3 that are trained in each craft skill.
33.	process_area_craft_fractions[4,*]	Decimal fraction of workers in process area 4 that are trained in each craft skill.
34.	process_area_craft_fractions[5,*]	Decimal fraction of workers in process area 5 that are trained in each craft skill.
35.	process_area_craft_fractions[6,*]	Decimal fraction of workers in process area 6 that are trained in each craft skill.
36.	process_area_craft_fractions[7,*]	Decimal fraction of workers in process area 7 that are trained in each craft skill.
37.	Technical_College	The number of students studying in each two-year degree area at technical colleges at the start of the simulation
38.	tech_college_fractions	Decimal fraction of all students entering two-year degree programmes that are entering fields needed by the nuclear power programme
39.	technical_degree_time	Duration in years of study for technician fields needed by the nuclear power programme
40.	Technician_Workforce_Pool	The total number of workers in the country working in each technician skill area not including the numbers in the defined work areas: excluding Related Industry, TSO and Experienced Technicians
41.	Techs_in_Related_Industry	The total number of workers in each technician skill area working in related industry
42.	Techs_in_TOS	The total number of workers in each technician skill area working in Technical Support Organizations Do not include those in Related Industry and Experienced Technicians
43.	Experienced_Technicians	The total number of workers in each technician skill area that have experience relevant to operating an NPP Do not include those in Related Industry and TSO
44.	tech_experience_rate	The number of technician workers each year that are sent to gain experience relevant to operation of an NPP

45.	tech_qualification_rate	The decimal fraction of the national technician workforce pool for each technician area that could be qualified to work in operation of an NPP
46.	process_area_tech_fractions[1,*]	Decimal fraction of workers in process area 1 that holds each technician skill
47.	process_area_tech_fractions[2,*]	Decimal fraction of workers in process area 2 that holds each technician skill
48.	process_area_tech_fractions[3,*]	Decimal fraction of workers in process area 3 that holds each technician skill
49.	process_area_tech_fractions[4,*]	Decimal fraction of workers in process area 4 that holds each technician skill
50.	process_area_tech_fractions[5,*]	Decimal fraction of workers in process area 5 that holds each technician skill
51.	process_area_tech_fractions[6,*]	Decimal fraction of workers in process area 6 that holds each technician skill
52.	process_area_tech_fractions[7,*]	Decimal fraction of workers in process area 7 that holds each technician skill
53.	Higher_Education	The number of students studying in each four-year degree area at universities at the start of the simulation
54.	engineering_university_fractions	Decimal fraction of all students entering four-year degree programmes that are entering fields needed by the nuclear power programme
55.	professional_degree_time	Duration in years of study for fields in engineering and sciences
56.	Professional_Workforce_Pool	The total number of workers in the country working in each professional degree area not including the numbers in the defined work areas: excluding Related Industry, TSO, and Experienced Professionals
57.	Engineers_in_Related_Industry	The total number of workers in each professional degree area working in related industry
58.	Engineers_in_TSO	The total number of workers in each professional degree area working in TSOs. Do not include those in Related Industry and Experienced Professionals
59.	Experienced_Professionals	The total number of workers in each professional degree area that have experience relevant to operating an NPP. Do not include those in Related Industry and TSO
60.	prof_experience_rate	The number of workers with professional degrees that each year are sent to gain experience relevant to operation of an NPP
61.	prof_qualification_rate	The fraction of the national professional workforce pool for each professional degree

		area that could be qualified to work in operation of an NPP
62.	process_area_eng_fractions[1,*]	Decimal fraction of workers in process area 1 that holds each professional degree
63.	process_area_eng_fractions[2,*]	Decimal fraction of workers in process area 2 that holds each professional degree
64.	process_area_eng_fractions[3,*]	Decimal fraction of workers in process area 3 that holds each professional degree
65.	process_area_eng_fractions[4,*]	Decimal fraction of workers in process area 4 that holds each professional degree
66.	process_area_eng_fractions[5,*]	Decimal fraction of workers in process area 5 that holds each professional degree
67.	process_area_eng_fractions[6,*]	Decimal fraction of workers in process area 6 that holds each professional degree
68.	process_area_eng_fractions[7,*]	Decimal fraction of workers in process area 7 that holds each professional degree
69.	mechanical_craft_hiring_rate	Year by year number of workers hired or released to work in mechanical fields during construction of the NPP. These are derived from HPC data.
70.	civil_craft_hiring_rate	Year by year number of workers hired or released to work in civil construction fields during construction of the NPP. These are derived from HPC data.
71.	phase_2_hiring_fraction	Decimal fraction of workers in the operating organization that are hired during Phase 2 [1]
72.	phase_3_hiring_fraction	Decimal fraction of workers in the operating organization that are hired during the construction phase (Phase 3) (Total Phase 2 and 3 are to be equal to 1)
73.	skill_area_fractions	Decimal fraction of staff in the operating organization in each skill level: manager, semi-skilled, skilled craft, technician, and professional
74.	reference_staff_size	Total workers in the operating organization for each type of NPP.
75.	second_unit_operation_factor	The decimal fraction of a single-unit NPP operating staff that would be required for a two-unit plant. Unit 2 is treated as a second unit with unit 1, unit 4 is treated as a second unit with unit 3.
76.	process_area_fractions	Decimal fraction of all workers in the operating organization that work in each process area
77.	other_industry_eng_fractions	Decimal fraction of workers with professional degrees employed in related industry that do work related to each process area
78.	other_industry_tech_fractions	Decimal fraction of workers with technician skills employed in related industry that do work related to each process area

79.	other_industry_craft_fractions	Decimal fraction of workers with craft skills employed in related industry that do work related to each process area
80.	TSO_eng_fractions	Decimal fraction of workers with professional degrees employed in TSO that do work related to each process area
81.	TSO_tech_fractions	Decimal fraction of workers with technician skills employed in TSO that do work related to each process area
82.	professional_initial_training_time	Duration of training after hiring for workers with professional degrees
83.	tech_initial_training_time	Duration of training after hiring for workers with technician skills
84.	craft_initial_training_time	Duration of training after hiring for workers with craft skills
85.	Standard_Outsourcing_Fractions	Decimal fraction of workers employed in operating the NPP in each process area that are provided by an outside contractor
86.	Agressive_Outsourcing_Fractions	Decimal fraction of workers employed in operating the NPP in each process area that are provided by an outside contractor in an aggressive outsourcing situation
87.	Euro_1_Outsourcing_Fractions	Decimal fraction of workers employed in operating the NPP in each process area that are provided by an outside contractor for the 1st European case
88.	Euro_2_Outsourcing_Fractions	Decimal fraction of workers employed in operating the NPP in each process area that are provided by an outside contractor for the 2nd European case
89.	User_Defined_Fractions	Decimal fraction of workers employed in operating the NPP in each process area that are provided by an outside contractor – defined by the user
90.	contracting_BOO	The decimal fraction of each process area to be staffed by the vendor under a BOO arrangement
91.	contracting_BOOT	The decimal fraction of each process area to be staffed by the vendor under a BOOT arrangement
92.	contracting_Turnkey	The decimal fraction of each process area to be staffed by the vendor under a Turnkey arrangement
93.	contracting_USER_1	The decimal fraction of each process area to be staffed by the vendor under a contracting arrangement defined by the user for case 1
94.	contracting_USER_2	The decimal fraction of each process area to be staffed by the vendor under a contracting arrangement defined by the user for case 2

95.	prof_recruiting_strategy	Target decimal fraction of professional degreed workers to be recruited from each workforce segment
96.	tech_recruiting_strategy	Target decimal fraction of technicians to be recruited from each workforce segment
97.	craft_recruiting_strategy	Target decimal fraction of craft skill workers to be recruited from each workforce segment
98.	regulatory_base_staff	Minimum number of workers required by the regulatory body regardless of NPP licence applications or operations
99.	regulatory_operating_staff	Number of additional staff required by the regulatory body for each operating NPP (not including base staff)
100.	regulatory_licensing_staff	Number of additional staff required by the regulatory body for each NPP licence application (not including base staff)
101.	regulatory_other_staff	A multiplier on the number of staff in the regulatory body that accounts for waste and other users.
102.	Regulatory_Workforce	Number of workers by professional degree area working for the regulator at the start of the simulation
103.	regulatory_staff_fractions	Decimal fraction of workers in each of the major areas of the regulatory body (Sum of all areas are to be equal to 1)
104.	engineering_grad_age_dist	Decimal fraction of students completing four-year degrees in each five-year age bin
105.	tech_grad_age_dist	Decimal fraction of students completing two-year degrees in each five-year age bin
106.	initial_workforce_age_fractions	Decimal fraction of all workers in each five-year age bin at the start of the simulation
107.	general_attrition_rate	Decimal fraction of all workers in each five-year age bin that will leave the workforce each year for job change, termination, retirement or any other reason
108.	nuclear_workforce_attrition_rate	Decimal fraction of workers in the operating organization or regulatory body in each five-year age bin that will leave the workforce each year for job change, termination, retirement or any other reason
109.	decommissioning_reference_staff	Size of workforce for decommissioning from reference documents
110.	decommissioning_skill_fractions	Distribution of workforce for decommissioning by skill level
111.	decom_phase_1_fraction	Decimal fraction of operating workforce released in phase 1 of decommissioning
112.	decom_phase_2_fraction	Decimal fraction of operating workforce released in phase 2 of decommissioning

113.	decom_phase_3_fraction	Decimal fraction of operating workforce released in phase 3 of decommissioning
114.	site_release_time	Number of years from completion of decommissioning until the site is released for other uses

APPENDIX II.
NUCLEAR POWER PLANT LIFECYCLE

II.1. INTRODUCTION

The *Nuclear Power Plant Lifecycle* module of the NPHR modelling tool gives a representation of the nuclear power programme. The function of this module is to establish the timing of events in the programme that would affect actions in the workforce. These events include the start of each phase, construction timeline, and beginning of operations.

II.2. NUCLEAR POWER PROGRAMME MODELLING

For the Member States working with the NPHR modelling tool, most plans for introducing nuclear power involve single unit plants or two-unit plants. In a few cases, countries are planning multiple sites and up to four units per site. The NPHR modelling tool has been modified to better align to these plans. The revised model allows for one or two sites with up to four units per site as indicated in Fig. 7 showing a snapshot from the model interface. Entering a future date that is beyond the end of the simulation means a unit will not be built. Figure 7 shows a programme for building two NPPs each with two reactors. Controls for the model allow adjusting the duration of the licence review and the duration of construction. These can be different for each site. The controls for licence extension add to the life of the NPP if the simulation is run long enough to include that consideration. The circles to the left of the duration controls are warning indicators. If the duration settings match or are longer than typical experience for previous NPPs, the circles will be green. If the duration settings are slightly optimistic the circles turn yellow. If the duration is set much shorter than experience, the circles will turn red.

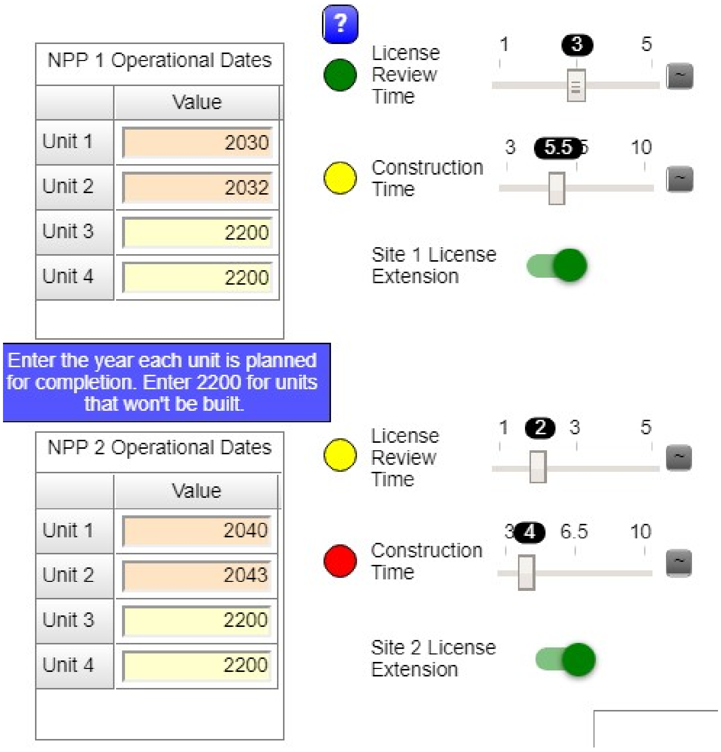

FIG. 7. Programme for building two NPPs each with two reactors.

II.3. TECHNICAL DETAILS

The challenge in changing to a structure that allows tracking the site structure of the NPP plan is maintaining the ability to track plant type at the same time. To do both, the model was modified to explicitly reflect site structure in the *Nuclear Power Plants* module. The structure now shows a lifecycle for each site. For countries that plan for three sites, this structure would be duplicated again. Note that each site structure may have a choice of NPP type.

The NPPs model screenshot at a high level may be found under the NIDS Interactive Platform. The model sectors contain the lifecycle models for each site. These are greatly simplified from earlier versions of the NPHR modelling tool. The models for each site are identical, but may have different factors for schedule, plant type, etc. Across the top are calculations that sum factors across sites, such as the total operating reactors. The tool also includes modules that contain models of power generation and fuel loading, although these calculations are not used anywhere else in the model.

The model elements in each site lifecycle representation have been modified with site 1 or site 2 at the start to distinguish which NPP they reflect. The constants in the model are generally shared between the site models, including reference values for reactor operational life, construction time, licensing time, etc. Where the model allowed for varying a factor that functionality was maintained for each site. For example, while the reference construction time for all sites is the same (***reactor construction time***), the model allows for the construction time for site 1 and site 2 to be varied independently through the interface control that adjusts ***site 1 construction time*** and ***site 2 construction time***.

The NPP lifecycle model represents the NPP from planning, through licensing, construction, and operation, to life extension and eventual shutdown and decommissioning. For most applications, the model is run for only part of the lifecycle. Adjusting the **Stop Time** control in the menu for model settings from the default value of 2050 to 2100 will have the model run for the entire NPP lifecycle. Some additional adjustments will be made to the model for this to work properly. Instructions can be found elsewhere.

A major difference from earlier versions of the NPHR modelling tool is that the lifecycle model is now an array of reactor units, where in earlier versions it was an array of reactor types. The converter ***site 1 reactor type*** is used throughout the model to translate from the NPP units to the reactor type. The stock ***Site 1 Reactors Planned*** is initially populated with the number of units set to be built prior to 2100. Upon completion of Phase 1, the model moves each NPP into Phase 2 which is represented as ***Site 1 Bid Preparation*** and ***Site 1 Ready to Bid***. The beginning of Phase 3 is governed by three factors: completion of bid preparation, readiness of the infrastructure, and the timing for the project. Bid preparation is modelled by the value of ***Site 1 Ready to Bid*** being greater than 0. Completion of infrastructure is set through ***MS2 Date*** which is a constant in the current model. Future model refinement could include Phase 2 details to calculate this date. Finally, the project schedule is determined through the date calculated in ***site 1 when to start***. ***Site 1 when to start*** takes the ***site 1 operational dates*** and calculates the starting year by subtracting the sum of ***commissioning time***, ***site 1 construction time***, and ***site 1 license review time***. If unit operational dates are set to beyond the simulation period (2050 default) they are not built during the simulation. Any units not planned need thus to be set to 2100 or later.

The calculations below the stock and flow set the durations for the conveyors for licensing, construction, and operations with the ability to vary these from the interface. The converter ***approval switch*** is a feature carried over from earlier versions of the NPHR modelling tool. If additional considerations for deciding to proceed with construction are desired in the model, their logic would be added in this converter.

The current model assumes NPPs will get a licence extension for a period defined by ***license extension time*** which has different values by reactor type. Shut down reactors may enter safe store for a period, then be entombed or undergo decommissioning and dismantlement. This part of the model contains some preliminary values and additional detail may be added in the future.

II.4. DATA

Data required for this module are defined in Table 5. Elements in the model that contain constants are shaded yellow. The constants for this module can be changed in the interface when running the model and are thus not included in the data file. Because the model is configured for embarking countries, the initial values for the stocks (operating NPPs, NPPs under construction, etc.) are set to 0. Additional constants appear in the *Energy Generation* and *Refuelling* modules. However, since these modules are not used in the overall model their details are not included here.

TABLE 5. NPP LIFECYCLE DATA

No.	Variable	Description
1	Phase 1 duration	Duration in years of Phase 1 of the Milestones Approach (See Ref. [1])
2	Commissioning time	Duration in years for commissioning a new unit
3	License review time	Duration in years for the review of a licence prior to start of construction. The data include values for each reactor type.
4	Reactor construction time	Duration in years for construction of the reactor unit or units. The data include values for each reactor type.
5	Reactor lifetimes	Duration in years the NPP is designed as normal lifetime. The data include values for each reactor type.
6	Site 1 transition time	Duration in years for transition of the NPP from operation to decommissioning, normally defined as removal of fuel from the unit.
7	Site 1 safe storage time	Duration in years the NPP is expected to be held in safe storage condition before decontamination and decommissioning (D&D) begins.
8	Site 1 D&D time	Duration in years for D&D of the NPP.
9	Site 2 transition time	Duration in years for transition of the NPP from operation to decommissioning, normally defined as removal of fuel from the unit.
10	Site 2 safe storage time	Duration in years the NPP is expected to be held in safe storage condition before D&D begins.
11	Site 2 D&D time	Duration in years for D&D of the NPP.

APPENDIX III.
EDUCATION SYSTEM CALCULATIONS

III.1. INTRODUCTION

To model the long-term workforce for nuclear power, the supply of workers through the educational system is needed. The NPHR modelling tool starts the educational system with the graduates from secondary school (termed high school in some countries) and uses statistics for these graduates' choice of continuing education, field of study, and success rates to estimate the number entering the workforce pools of interest to the nuclear power programme.

For some Member States, their educational system may differ from the description of the educational system used in the NPHR modelling tool. Some Member States may also want to model educational initiatives for student in primary or secondary education. Alternate models will be discussed in this document. It is also recognized that the availability of statistics and the format of those statistics affects how the model is structured. The IAEA will assist Member States that need to modify the model for their systems.

III.2. THE EDUCATION MODEL

The *Education* module begins with high school graduates and uses statistics to estimate the numbers following each of four post-secondary pathways:

- No post-secondary formal training;
- Craft (vocational) skill training;
- Technical school (2 years);
- University (4 years).

The graduates entering each of these pathways are divided into the skill and degree areas of interest to the nuclear power programme and those areas that are not of interest to the nuclear power programme. The skills required for a nuclear power programme that are included in the model are shown in Table 6. Additional skills are required, but skills that are expected to be readily available and do not require any specialized training are not included in the model at this time.

The Education model tracks these pathways to provide the supply of graduates into the workforce. The model accounts for attrition from the education programme. The model also includes representation of initiatives to enhance the supply of graduates, namely:

- Increased enrolment and retention in secondary education;
- Expansion of specific degree programmes;
- Initiatives to increase enrolment in Science, Technology, Engineering, and Math programmes.

TABLE 6. SKILLS AS SHOWN IN THE NPHR MODELLING TOOL

No.	Stage	Skills	Type
1	Regulatory body (based on U.S. Nuclear Regulatory Commission)	Technical Area	
		Accounting	
		Legal	
		IT	
		Investigators	
		Engineers	NE
			ME
			ChE
			EE
			Other
		Scientists	Chem
			Physics
			Biology
			Physical Sci
			Materials
			Health Physics
			Geologists
			Hydrology
			Seismology
		Security	
		Safeguards	
2.	Operating organization (IAEA Workforce Planning, US data from BLS)	Four year	Nuclear
			Electrical
			Civil
			Mechanical
			Chemical
			Ind, ESH, Other
			Physics
			Chemistry
			Other science
		Technicians	Industrial Eng Tech
			Electrical
			Mechanical
			Rad Protection
			Chemical Nuclear
		Craft	Electricians

TABLE 6. SKILLS AS SHOWN IN THE NPHR MODELLING TOOL

No.	Stage	Skills	Type
			Pipefitters Haz. Mat workers Operating personnel Power Dispatchers
3.	Construction (See Ref. [6])	Boilermakers Carpenters Electricians/Instrument Fitters Iron Workers Insulators Laborers Masons Millwrights Operating Engineers Painters Pipefitters Sheetmetal Workers Teamsters	

III.3. Technical Details

Figure 8 shows a simple model for population growth and secondary graduation. The factor ***population growth*** is the net growth rate per year, accounting for both birth and death. The model is intended to model multiple decades of a nuclear power programme. For most countries, the population growth rate will change over this timescale. Thus, ***population growth*** is a graphical function that varies over time and can be changed in the model interface. The factor ***high school graduation rate*** is the fraction those of school age that complete secondary education. The calculation of ***annual secondary graduates*** is thus the product of ***high school graduation rate*** with the fraction of ***total population*** that is of school age. For the current model, the fraction of the total population that is of school age is estimated as 1/75 of ***Total Population***, which is a reasonable approximation for populations that are evenly distributed. For populations that are not evenly distributed a more detailed calculation is needed.

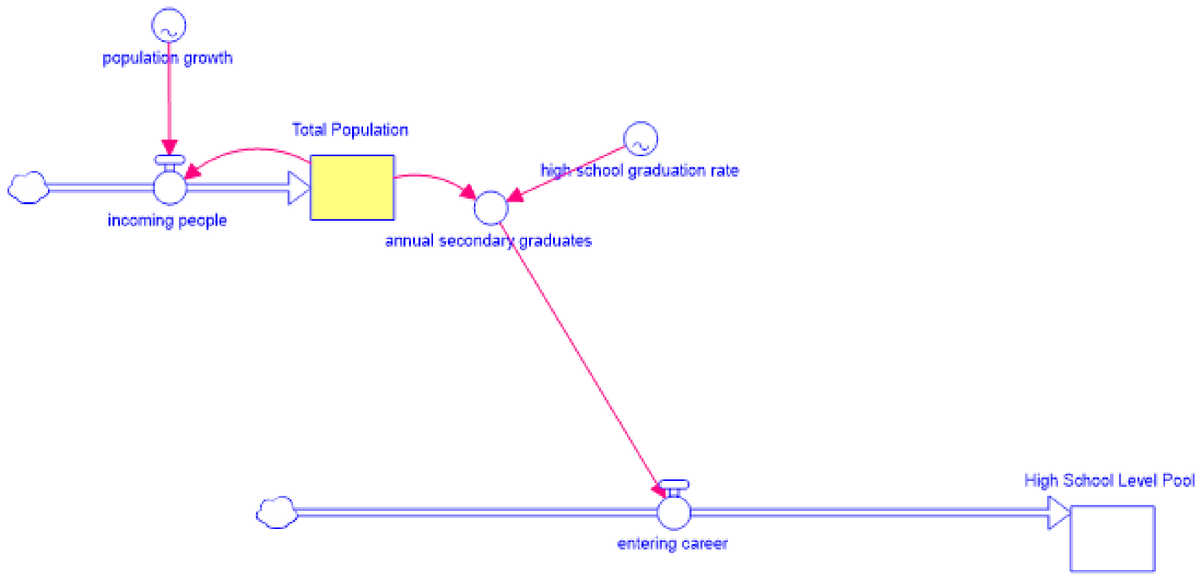

FIG. 8. Estimating secondary graduation from national population.

Figure 9 shows the distribution of secondary education graduates to post-secondary career paths. The converter ***professional path fractions*** contains an array of the fractions of secondary graduates following each of the four career paths defined above. The number of secondary graduates taking each path is then the product ***professional path fractions * High School Level Pool.*** These totals are then distributed to each path as follows:

- Other Careers – secondary graduates that do not pursue post-secondary training. These are skills that are not considered further in the model;
- Craft skills – Those receiving vocational training as post-secondary career preparation. Part of this path features skills that are not of interest to the nuclear power programme, and the path ***nonNuc trades*** removes them from further consideration in the model. The path ***entering trade school*** includes the trades that are considered in the nuclear programme;
- Technical Schools – secondary graduates pursuing two-year degrees are likewise split into those pursing studies not of interest to the nuclear programme, ***entering nonNuc tech school***, and those entering fields of interest, ***entering technical college***. Those following ***entering nonNuc tech school***, are not considered further in the NPHR modelling tool;
- University – secondary graduates entering four-year academic programmes are split into ***entering nonEng univ***, which are not considered any further, and ***entering engineering program*** which includes science and engineering fields.

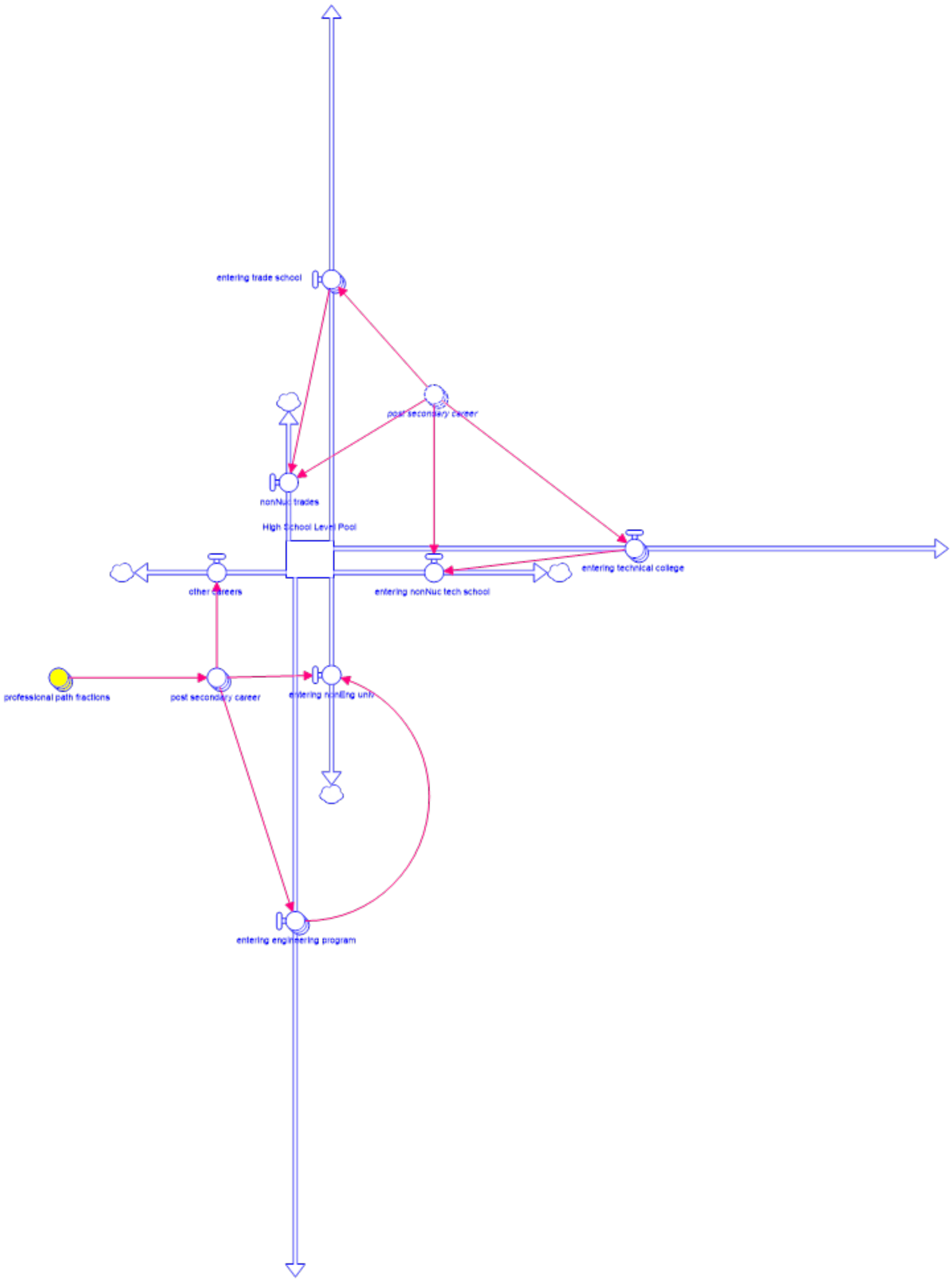

FIG. 9. Model of secondary graduates choosing post-secondary career paths.

Each path is split between the skills of interest to the nuclear power programme and the skills that are not considered any further. This calculation is illustrated in Fig. 10 for four-year university studies, while similar calculations are made for the technician and craft workforce. The converter ***engineering university fractions*** contains an array of the fractions of university freshmen studying engineering and science disciplines. This fraction multiplied by the numbers entering university in ***professional path fractions * High School Level Pool*** gives the totals entering each engineering or science field. The remainder of the total entering university follow ***entering nonEng univ*** and are no longer considered in the model.

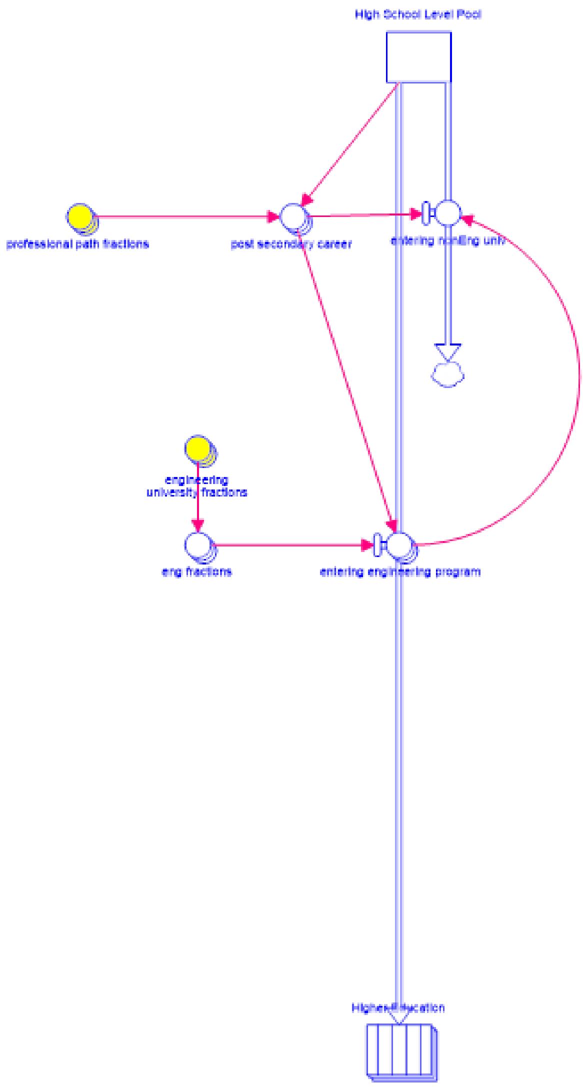

FIG. 10. Populating the higher education fields of interest.

Initiatives to increase entry into certain fields have the effect of changing the fractions entering each field. Some initiatives have the effect of increasing overall enrolment in the sciences and engineering. These can be modelled using a multiplier on the overall enrolment into science and technology fields. This is done by the factor ***STEM Multiplier***, which can be changed in the interface and adjusts the flow into four-year programmes. Alternatively, an initiative may be for a specific degree programme, such as nuclear engineering. This is modelled by anticipating growth to a target enrolment level over a period of years.

The factors in Fig. 11 are used to model a linear growth in enrolment between the years specified in ***eng program start year*** and ***eng program full year*** to the level in ***target enrollment eng***. These factors can be set in the interface. The same logic is repeated for two-year technical colleges and craft skill training programmes.

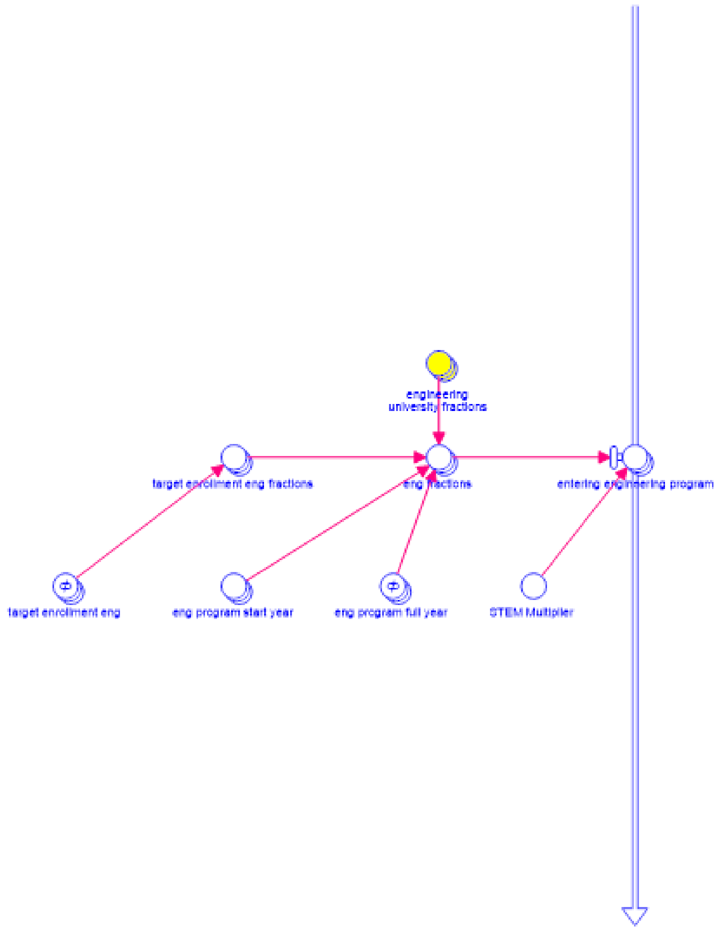

FIG. 11. Model details for changing enrolment in a degree programme over time.

Each post-secondary training path is characterized by a duration and success (or drop out) rate. Both factors may be adjusted in the interface.

Graduates from each training path enter the workforce, represented by three workforce pools: ***Professional Workforce Pool***, ***Technician Workforce Pool***, and ***Craft Labor Pool***. Workers then move from these pools according to the model for the workforce.

III.4. DATA

Elements in the model that contain constants are shaded yellow. The data in the education model are defined in Table 7.

TABLE 7. EDUCATION MODEL DATA

No.	Variable	Definition
1	Total_Population	Total population for the country
2	Population Growth	Net annual rate of growth of the population of the country. This is a graphical converter that needs to be set in the model.

TABLE 7. EDUCATION MODEL DATA

No.	Variable	Definition
3	High School Graduation Rate	Fraction of the population that completes secondary education. This is a graphical converter that needs to be set in the model.
4	trade_school_attrition_rate	Fraction of those enrolled in craft training programmes that leave the programme in a year without completion
5	tech_dropout_rate	Fraction of students studying the technician areas needed by the nuclear power programme that terminate their studies for any reason
6	university_dropout_rate	Fraction of students studying the professional areas needed by the nuclear power programme that terminate their studies for any reason
7	professional_path_fractions	Fractions of those completing secondary school that choose among the following career paths: Labour - no further education Skilled craft – career training, apprenticeships, or on-the-job training Technicians - two-year degree programmes Professional - four-year degree programmes
8	Trade_School	The number of students studying each craft skill at trade schools at the start of the simulation
9	trades_nuclear_fraction	Fraction of all students entering trade schools that are entering training for skills needed by the nuclear power programme
10	Trade_school_duration	Number of years craft workers receive formal training before joining the workforce, by craft skill.
11	Technical_College	The number of students studying in each two-year degree area at technical colleges at the start of the simulation
12	tech_college_fractions	Fraction of all students entering two-year degree programmes that are entering fields needed by the nuclear power programme
13	technical_degree_time	Duration in years of study for technician fields needed by the nuclear power programme
14	Higher_Education	The number of students studying in each four-year degree area at universities at the start of the simulation

TABLE 7. EDUCATION MODEL DATA

No.	Variable	Definition
15	engineering_university_fractions	Fraction of all students entering four-year degree programmes that are entering fields needed by the nuclear power programme
16	professional_degree_time	Duration in years of study for fields in engineering and sciences

Data for the education model are managed on the Education worksheet of the NPHR Excel data file. The worksheet has four data sets:

- US data – detailed data from the United States educational statistics;
- Example – data in which the US data are scaled by the country population;
- Default – data in which the US data are scaled by the country population and the secondary graduation rate, along with calibration factors for initial enrolment;
- Custom – a data table set up for user input.

Each of these data sets contain data for the education model. To represent the number of workers entering each field, the model relies on population and education statistics. The initial values in the model are the population and enrolment in each educational track. The changes in these values over time come from the population growth rate, rate of secondary completion, and fractions choosing each career path and field. These data are often available from national statistics and data from educational institutions.

APPENDIX IV.
WORKFORCE ATTRITION CALCULATIONS

IV.1. INTRODUCTION

A feature of workforce dynamics is losing workers, or workforce attrition. Attrition may occur for many reasons; retirement, change of jobs or careers, termination for cause, personal reasons, health issues, and more. With the long lifecycle of an NPP, all workers will leave the workforce at some point. Each departure results in recruiting, hiring, and training a replacement. With a large workforce, this results in a steady flow of workers into an organization. The NPHR modelling tool takes attrition into account in all organizations and in the overall national workforce. The model is designed to be flexible in accounting for causes of worker attrition.

IV.2. WORKFORCE ATTRITION MODEL

The attrition model is predicated on four drivers for why workers might leave an organization. In the NPHR modelling tool these are described as:

- Job change – the worker pursues a different job, within the same organization or in a different organization;
- Career change – the worker leaves their field of expertise and pursues a different field;
- Termination – the worker is removed from their job for behaviour or performance;
- Retirement – the worker retires or otherwise leaves the workforce.

Note that with rough estimates of the rates for each of these, the definitions of each do not need to be rigorous; other causes may be assumed to be captured within the same rate. Retirement is the most common reason for workforce attrition and the likelihood a worker retires is closely correlated to worker age. Therefore, attrition rates are defined as functions of worker age and it is necessary to include in the model a representation of the age distribution of the workforce and how that distribution changes over time.

The age distribution calculation starts with an initial distribution of ages in the workforce, summed into 5-year bands for convenience. As workers enter the workforce from the educational system their ages are combined into the general workforce distribution. At the same time, the model of attrition defines a likelihood of workers in each age group leaving the organization.

IV.3. TECHNICAL DETAILS

The NPHR modelling screenshot that shows the attrition calculations for engineers and scientists can be found under the NIDS Interactive Platform. An identical structure is used for calculation of attrition for the technician workforce. The elements in this calculation are arrays of age groups, 18–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, and 65–69. All age groups are 5 years except the youngest which is two years. The data in each element are the numbers or fractions of workers in each age group.

The science and engineering attrition calculation has three stocks representing the workforce ages:

- ***Workforce Pool Age*** – age distribution of the overall workforce;
- ***Nuclear Workforce Age*** - age distribution of the operating organization workforce;
- ***Regulator Workforce Age*** – age distribution of the regulator workforce.

Aging of the workforce is represented by each time interval moving 1/5 of the workers in each five-year age band (1/2 of workers for the 18–19 age band) to the next higher age band. This is done in the bi-flows ***age transition pool***, ***age transition workforce***, and ***age transition regulator***.

University graduates entering the workforce are added by applying an age distribution (***engineering grad age dist***) to the number of graduates from ***entering professional pool***. Workers are removed from ***Workforce Pool Age*** by the rates defined in ***general attrition rate***.

The rate of attrition from the general workforce may be different from attrition from the nuclear workforce. To allow this difference, attrition from ***Regulator Workforce Age*** and ***Nuclear Workforce Age*** follows the rates in ***nuclear workforce attrition rate***.

IV.5. DATA

Elements in the model that contain constants are shaded yellow. In the attrition model the data are as listed in Table 8. The age distributions are defined in the data file in the tab *AgeDistribution* and the attrition rates are defined in the tab *Attrition*. Multiple distributions may be defined in the data file and selected for import into the model.

TABLE 8. WORKFORCE ATTRITION MODEL DATA

No.	Variable	Description
1	engineering_grad_age_dist	Fraction of students completing four-year degrees in each five-year age bin
2	tech_grad_age_dist	Fraction of students completing two-year degrees in each five-year age bin
3	general_attrition_rate	Fraction of all workers in each five-year age bin that will leave the workforce each year for job change, termination, retirement, or any other reason
4	nuclear_workforce_attrition_rate	Fraction of workers in the operating organization or regulatory body in each five-year age bin that will leave the workforce each year for job change, termination, retirement, or any other reason

APPENDIX V.
CRAFT LABOUR MODEL

V.1. INTRODUCTION

The first version of the NPHR modelling tool for the NPP construction workforce was based on a single reference that described the workforce in terms of skills breakdown and peak on-site workforce. These data did not distinguish between projects involving the construction of a single unit and multi-unit projects and did not give any basis for how the workforce changed over time as the project progressed. For simulations of programmes with multiple sites, the model did not allow for having different contracting approaches for each site.

The model for craft labour has been substantially revised to accomplish several objectives:

- Provide better flexibility in representing the overall nuclear power programme;
- Distinguish between single reactor and multi-reactor construction projects;
- Incorporate new data on construction workforce;
- Include better resolution of construction time-phasing;
- Model different contracting approaches for second plants.

The first two objectives are enabled by revisions in the NPP lifecycle model. See the description for these revisions in the document NPHR V3.0 Nuclear Power Plants under the NIDS Interactive Platform folders. How these objectives are met with the *Craft Labour* revisions is discussed below.

V.2. NEW CONSTRUCTION WORKFORCE DATA

The NPHR modelling tool is now able to use workforce planning data from the HPC project [5] as summarized in Fig. 12. The data show time-phased workforce for site and structures (civil construction skills), equipment installation (mechanical, electrical, as well as instrumentation and control engineer skills), and management. Note that these data are for construction of a two-unit NPP.

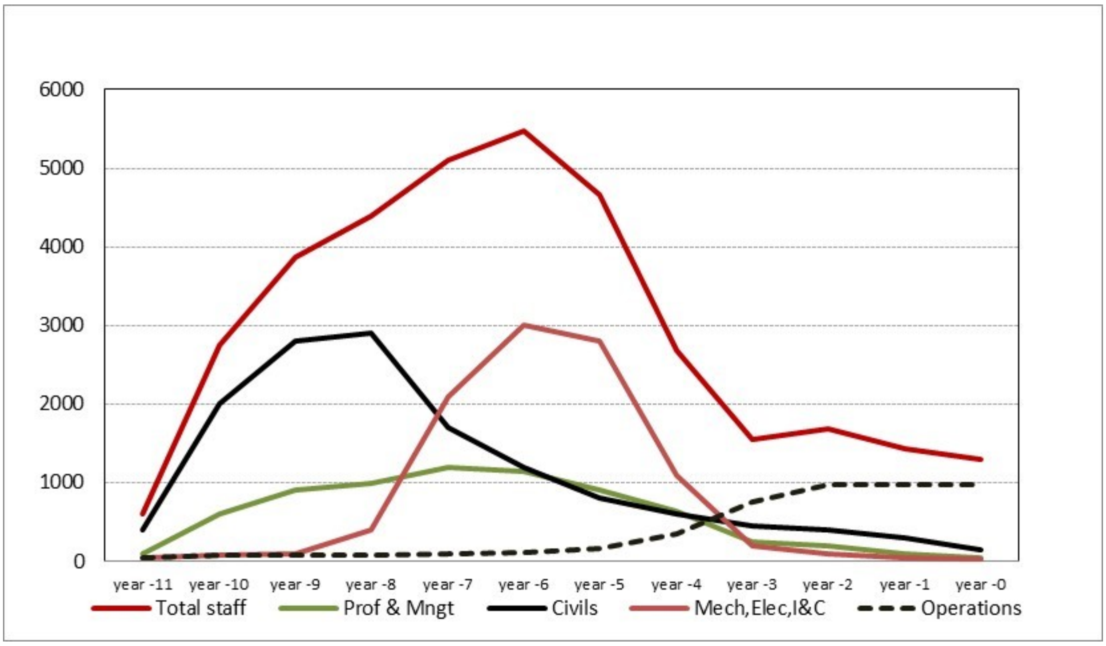

FIG. 12. Workforce for the HPC construction phase.

For workforce planning it is useful to identify the construction workforce as being recruited from the local workforce or being recruited outside the country by the vendor. Figures 13 and 14 show model results for the construction workforce for building two NPPs with two reactors each.

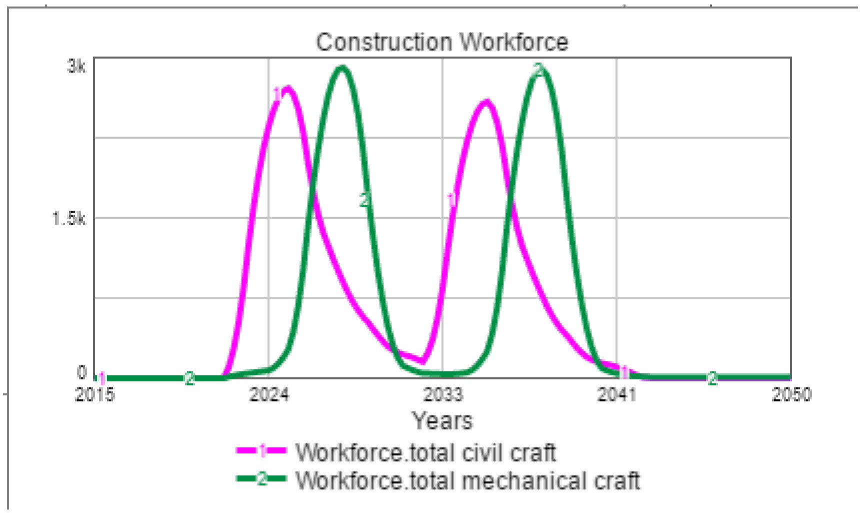

FIG. 13. Model results for the construction workforce for building two NPPs with two reactors each: civil craft versus mechanical craft.

The construction workforce is shown in Fig. 13 as civil craft versus mechanical craft and in Figure 14 as indicating being sourced from the domestic workforce versus being provided from outside the country by the vendor. In Fig. 13 the total workforce is the same for the two NPPs. This is an assumption that can be varied in the model. Figure 14 shows an example where more of the workforce for the second NPP came from the country and less from the vendor. This represents a plan by the country to use construction of the first NPP to develop skills that would be used in construction of the second NPP.

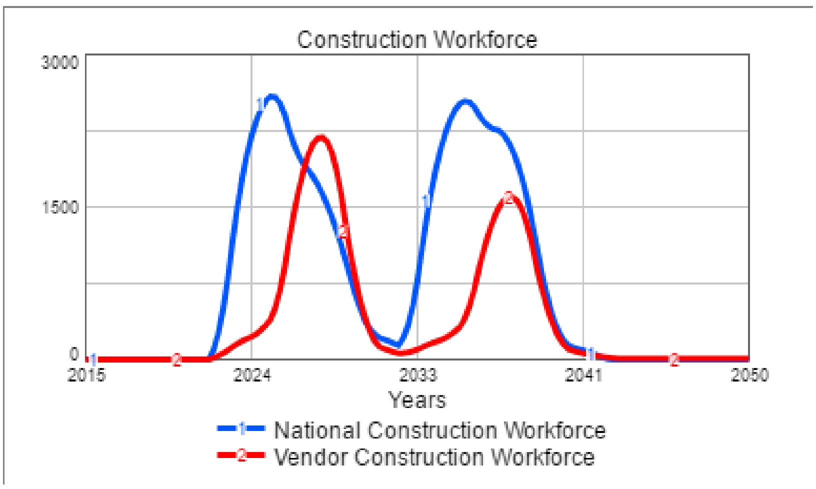

FIG. 14. Model results for the construction workforce for building two NPPs with two reactors each: domestic workforce versus being provided from outside the country by the vendor.

V.3. DATA

The workforce data is available as staffing numbers per year. The model needs the numbers in rates. This conversion is done in the *Craft labour* tab of the data spreadsheet. The data are by year before project completion indicated by the numbers across the top counting down from 11 to 0. At the bottom of the spreadsheet is an interpretation of the data by project phases, yellow being site preparation, blue being facility construction and equipment installation, and green being transition to operations.

The hiring rate data are imported into the graphical variables ***civil craft hiring rate*** and ***mechanical craft hiring rate***. These are mapped to civil skill areas and mechanical skill areas using the arrays in ***craft civil*** and ***craft mechanical*** which contain the percentage of the workforce for each skill that are part of the craft and mechanical phases of construction. The fractions are set in the data file which is configured to ensure the total of the fractions is 100%. In the data file it is assumed that civil skills include carpenters, insulators, labourers, masons, millwrights, sheet metal workers, and teamsters and mechanical skill areas include boilermakers, electricians, iron workers, and pipefitters. The current ***craft civil*** and ***craft mechanical*** put each skill in one category or the other. Alternatively, the skills may be split between the categories by changing the fractions in the data file.

The hiring curve is then applied to the flow between the ***Qualified Craft Labor*** stock and the ***Craft Labor Building Plants*** stock through use of the DELAY function. The syntax is

DELAY(<input>, <delay duration>, [<initial>])

Where <input> is the hiring curve and <initial> is the value prior to the input. The delay function keeps the value at <initial> until the simulation reaches a time equal to <delay duration>. In this case, the delay duration is the number of years before operations that hiring for construction needs to start, accounting for construction time, commissioning, site preparation, etc. The delay is calculated in the variable ***site 1 hiring lead time***. The delay time apart from construction duration is encapsulated in a variable ***civil lead time*** which has a default value of 3.

Also applied to the hiring rate is the ***site 1 craft fraction from vendor*** which selects the specified fraction of workers from the country's qualified craft workforce and the remainder from the vendor.

Note that all calculations marked 'site 1' are duplicated with 'site 2'.

Distinguishing between single unit and multi-unit construction projects

The data set for construction workforce is for a two-unit NPP. However, some country plans are for a single unit NPP. Furthermore, if the time between the construction projects is significantly long a two-unit construction project may resemble two single-unit projects. Finally, the model can also show four-unit NPPs. Modelling these cases requires some assumptions:

- A single unit plant will have the same workforce profile for the construction workforce as a two-unit plant but reduced by a factor;
- A two-unit plant for which the construction of the two units is separated by a significant number of years will have a profile for construction workforce of two single-unit construction projects;
- Four-unit NPPs will be modelled as two projects that each construct a two-unit NPP.

Figures 15–18 show illustrative results of this approach. Figure 15 shows the construction workforce for a two-unit NPP with the units reaching completion two years apart, reflecting the original data. Figure 16 shows the workforce for a single unit NPP, where it is assumed to require 60% of the two-unit NPP workforce to execute on the same schedule. The 60% factor is built into the converters ***site 1 dual unit*** and ***site 2 dual unit*** which can be adjusted as an assumption. Figure 17 shows the workforce for a two-unit NPP where the units are constructed four years apart each requiring 60% of the two-unit workforce. Figure 18 shows the workforce for construction of a four-unit site which is modelled as two sequential two-unit construction projects.

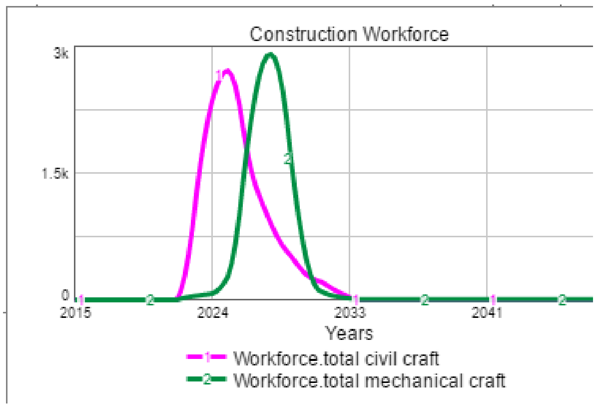

FIG. 15. Construction workforce for a two-unit NPP with the units reaching completion 2 years apart

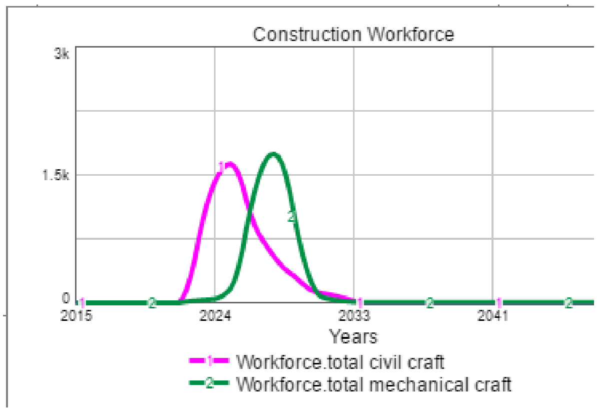

FIG. 16. Workforce for a single unit NPP, where it is assumed to require 60% of the two-unit NPP workforce to execute on the same schedule.

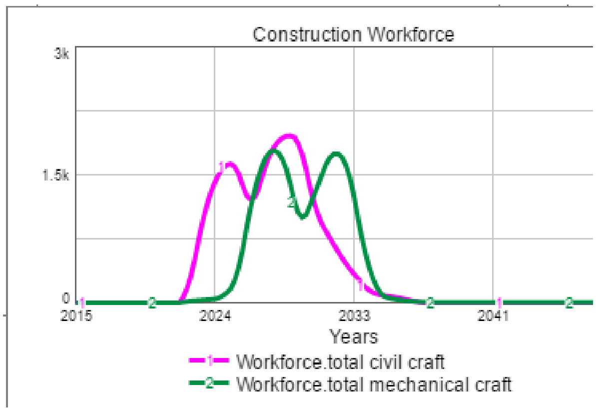

FIG. 17. requiring 60% of the two-unit workforce.

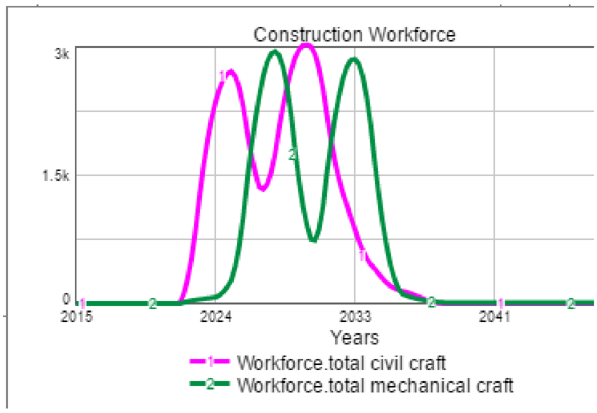

FIG. 18. Workforce for construction of a four-unit site which is modelled as two sequential two-unit construction projects.

V.4. TECHNICAL DETAILS

The craft labour workforce is shown in Fig. 19. Workers completing craft training programmes (see the discussion on modelling educational systems in Appendix III) enter the ***Craft Labor Pool***, which is an array of craft skill areas. To identify skills that require and additional level of skill, the model distinguishes between the general labour pool and the craft workers that would be qualified to work at an NPP. This is done by using the factors in ***craft nuclear qualification rate***, which specifies a fraction for each skill that would be qualified for nuclear work. For some low-skill areas the factor is 1 so all workers would be qualified while some more demanding skills would have a low fraction of qualified workers. Those that are qualified are moved to the stock ***Qualified Craft Labor***.

For craft labour a constant attrition factor, ***craft attrition rate***, is applied to all pools of workers.

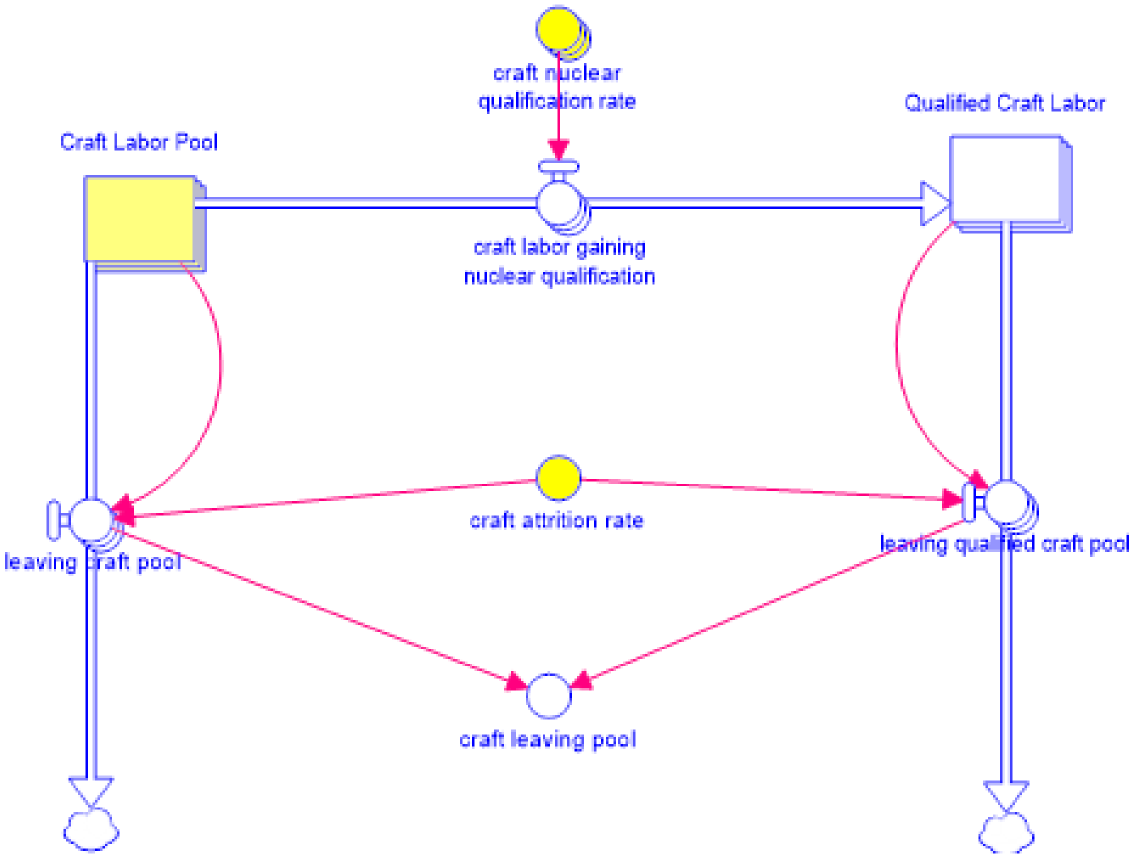

FIG. 19. The model of craft labour workforce.

Craft workforce are used in construction and operations. Each organization draws from the same national workforce pool.

Figure 20 shows the workforce for construction being recruited from the qualified workforce pool. Note that ***hiring for construction*** is a bi-directional flow. Workers are hired for the construction period and returned to the workforce pool when no longer needed. Some workers are lost to attrition during the construction period. These are replaced using the factor ***craft construction attrition*** being fed into ***hiring for construction***.

Calculation of the demand for craft workers for construction is made in a sector entitled *Construction Workforce*. Part of this sector is shown in Fig. 20. The hiring rates from the data file are stored as graphical converters ***civil craft hiring rate*** and ***mechanical craft hiring rate***. The converter ***site 1 craft fractions per plant*** contains the fraction of each craft skill in the overall craft workforce, so multiplying by the hiring rate gives the number to be hired for each skill. The factors ***craft civil*** and ***craft mechanical*** further divide the craft workforce into the time phases as in Fig. 12. These are combined in ***site 1 craft required***. An additional factor ***site 1 construction staff variable*** is applied to allow the user to increase or decrease the overall workforce requirements from the interface. An identical calculation is made for site 2.

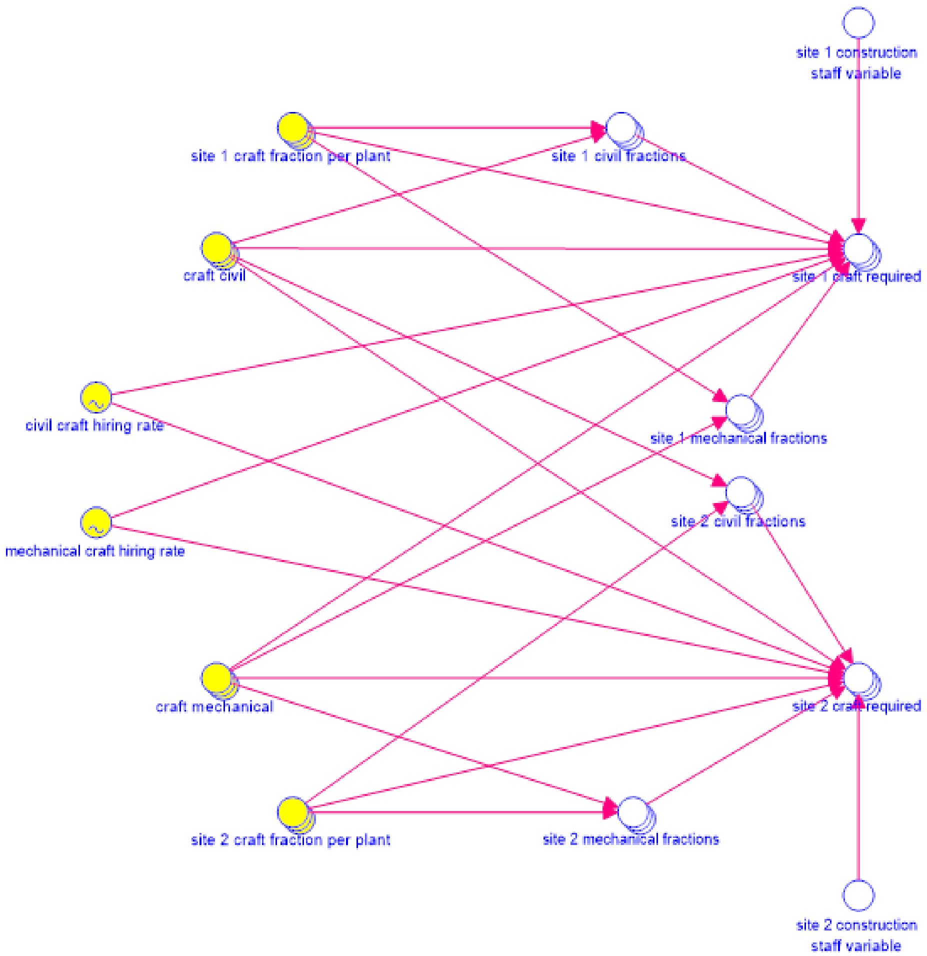

FIG. 20. Calculating demand for craft construction workforce.

The model allows the user to examine different options for meeting the staffing requirements. The vendor will typically be responsible for the construction workforce, but the contract may specify a level of domestic sourcing for this workforce. The model for this is shown in Fig. 21.

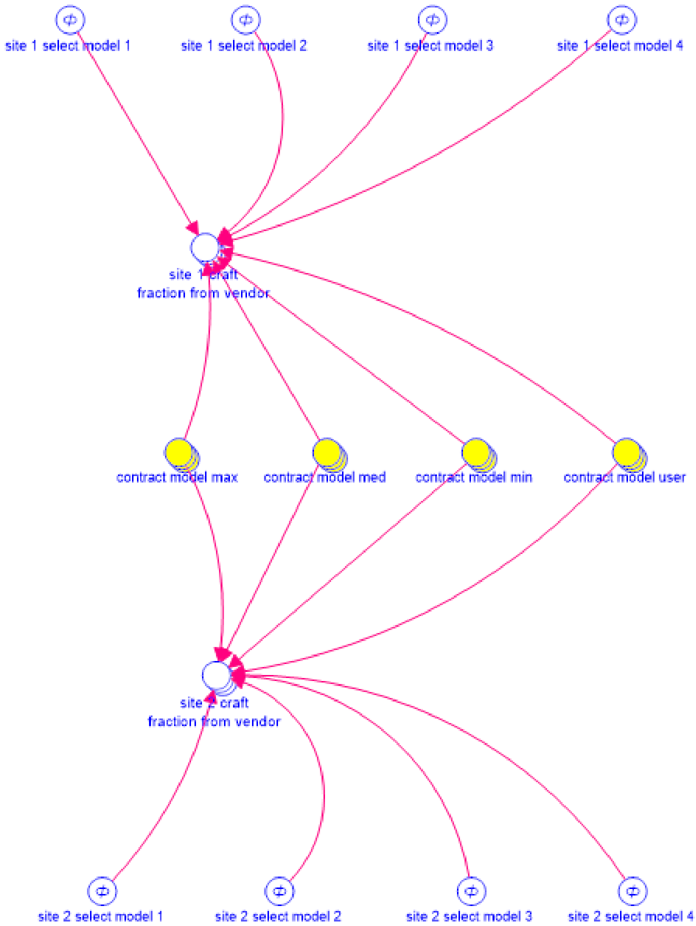

FIG. 21. The model for selection of EPC contracting approaches.

In Fig. 22 the converters ***site 1 domestic craft required*** and ***site 2 domestic craft required*** are ghosted from the construction workforce calculation. In ***hiring for construction***, the timing for these demand levels are delayed based on the calculation of lead time before operation. The converter ***site 1 lead time*** calculates the time in the simulation that hiring construction workers for site 1 begins.

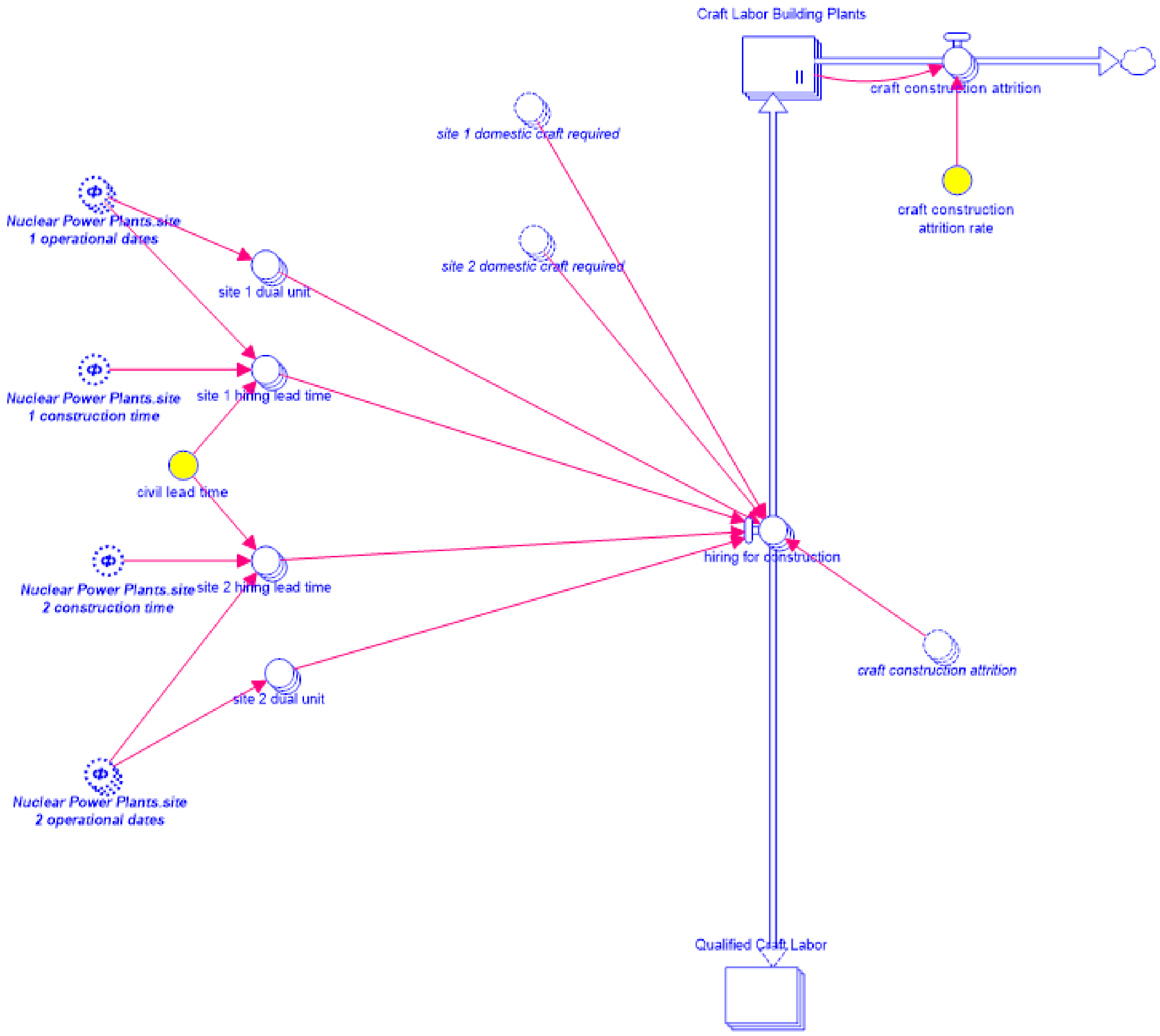

FIG. 22. The model for hiring craft workers for construction.

The model accounts for craft workers in related industry. The initial value for ***Craft in Related Industry*** is set in the data file and the model sets a growth rate, set in the interface, for this part of the workforce. Related Industry is a potential source of experienced workers.

Figure 23 shows the calculation for recruiting from related industry. The factor ***other industry craft fractions*** sets a fraction of each skill in ***Craft in Related Industry*** that might be candidates for work at an NPP. These factors would represent knowledge of the industry in the country and the skills available in that part of the workforce. The value of ***craft from related industry*** is the desired number of recruited workers from the recruiting calculation for the operating staff (see Appendix VII of this document). The model attempts to recruit this number and any shortfall is calculated in ***shortage of craft from RI***. This shortage is then recruited from the qualified (but inexperienced) workforce pool.

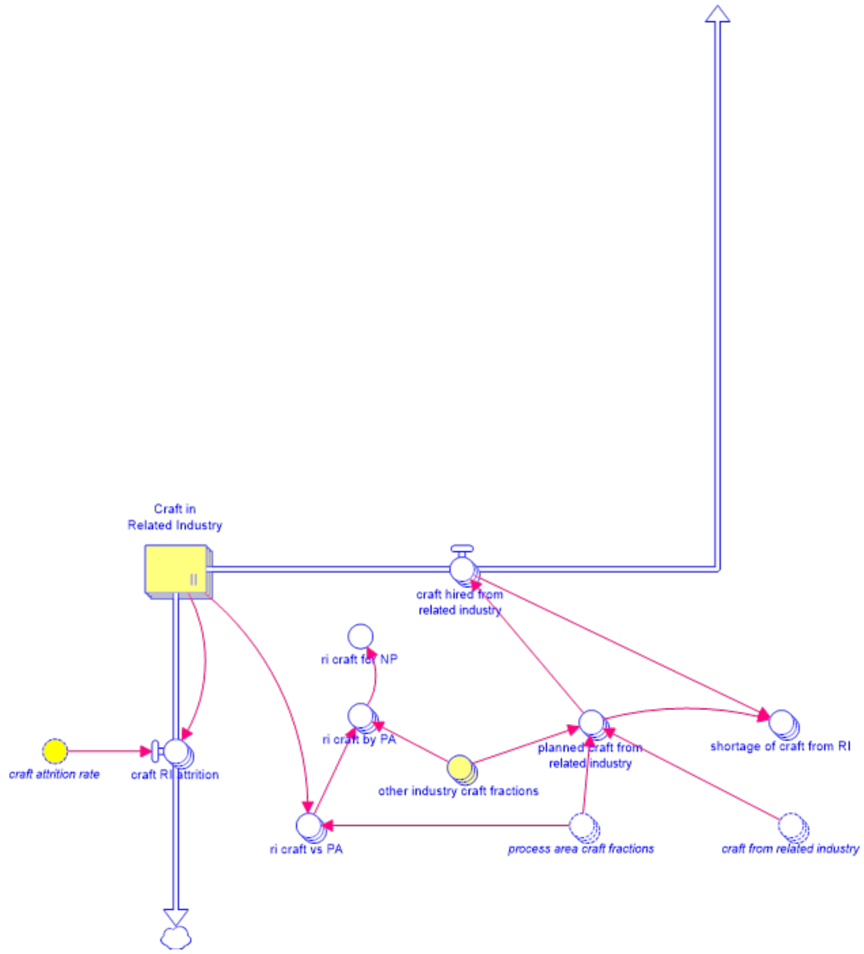

FIG. 23. Calculation for recruiting craft workers from related industry.

The converters ***site 1 dual unit*** and ***site 2 dual unit*** determine if the model treats an NPP as a single-unit NPP or part of a two-unit NPP based on the operational dates and applies the scaling multiplier as appropriate. In this converter, if the operational date for unit 2 is more than 3 years after unit 1, the construction projects are treated as independent single-unit projects and the model applies the scaling factor to the hiring.

APPENDIX VI.
OPERATING STAFF FOR NEW NPPs

VI.1. INTRODUCTION

This appendix discusses the model for staffing requirements for new NPPs during Phase 2 and Phase 3. The use of this calculation in the overall model is discussed in the technical brief on operating staff.

The NPHR modelling tool calculates the staff hired by the operating organization during the period when the plant is undergoing licence review and construction. The model uses the reference staffing curve that can be found in multiple references. In Fig. 24 the staff for the operating organization is indicated by the green curve. Hiring starts in Phase 2 then increases during Phase 3 until reaching full staffing levels near plant startup. Staffing by skill level is not uniform during this time. Managers and professional staff are hired first, with technicians, skilled craft, and semi-skilled staff being hired later. The NPHR modelling tool is designed to reflect these considerations.

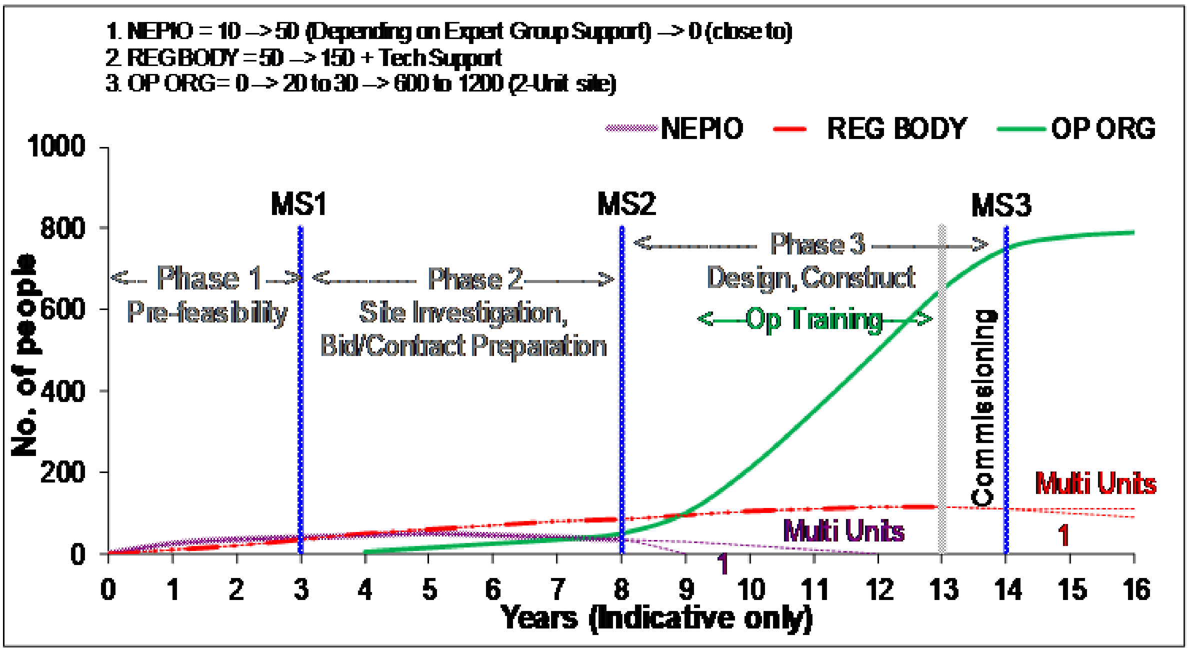

FIG. 24. Staffing during the Milestones Process showing staffing by organization and phase.

Previous versions of the NPHR modelling tool used the rates of staff increase in each phase to establish a hiring rate. The rates are calculated as an average rate over each phase:

Hiring rate in a phase = Total Operations Staff Level*Fraction hired during phase/duration of phase

This calculation can be done for each skill level. The model moves this number of workers during each time interval from the source of workers into the nuclear workforce.

For operating NPPs the model calculates the number of hired workers to maintain the operations staff at a steady-state level. One way to do this is to add all workers leaving the workforce for retirement, job change, or other reasons and hire an equal number to replace them. For several reasons, this was not a good way to calculate sustainment. Instead, the NPHR modelling tool calculates a desired staffing level, compares that to the current staffing level, and hires the difference. While this approach works better for sustaining staff, it poses a conflict with the rate approach during startup.

This appendix describes the changes to the model that have been made to the calculation of staffing for the operating organization in Phase 2 and Phase 3.

VI.2. OPERATING STAFF MODEL

Calculations for staffing for new plants during Phase 2 and Phase 3 are located in the *New Plant Staff* sector in the *Workforce* module of the NPHR modelling tool. The total operations staff size for several types of NPP are found in the variable ***reference staff size***. The array ***Nuclear Power Plants.site 1 reactor type*** is used to select the reference staff size for the type of plant being modelled. The user can scale the staff size using the control ***site 1 staff size factor*** that is controlled from the interface. These reference staff sizes can be found in the input data file. Figure 25 shows the calculation of the plant staff size. There is an identical calculation for site 2.

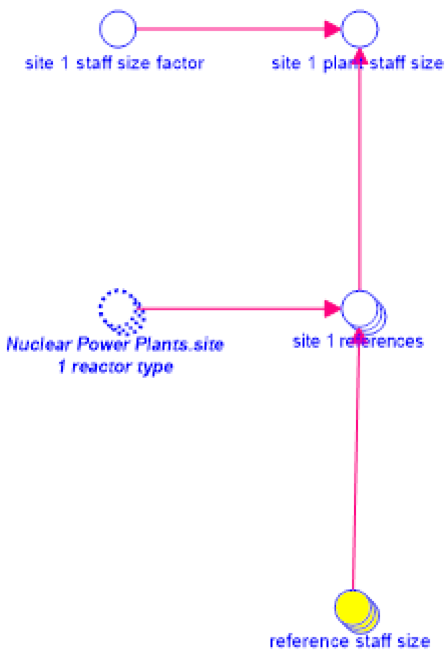

FIG. 25. Calculation of plant staffing.

The challenge for modelling the curve shown in Fig. 24 is that the timing of the curve comes from the schedule for each unit, while the amplitude varies by skill level. Maintaining both dependencies makes the model structure slightly confusing. The model first calculates the hiring rate during Phase 2 and Phase 3 by NPP unit as if the entire workforce were hired in each phase. This is shown in Fig. 26 where the variable ***site 1 staff rate during phase 2 by unit*** has a value of ***site 1 plant staff size*second unit operation factor/Nuclear Power Plants.site 1 bid prep duration*** for each year the bid is being prepared (i.e. *site 1 bids*>0) and a value of 0 in other years. The factor ***second unit operation factor*** accounts for staff efficiencies for operating a multi-unit site. For the first unit, the plant requires the full reference plant staff. A second unit will require an incremental staff that is less than a full reference plant staff. This factor is derived from the single unit and dual unit staff models in the Appendix I of the Workforce Planning document [2] and calculated in the data file in the staffing tab to be 0.47. The third and fourth units are also treated as a two-unit site, requiring the full reference staff for the third unit and a reduced staff for the fourth unit. This calculation is repeated for site 2.

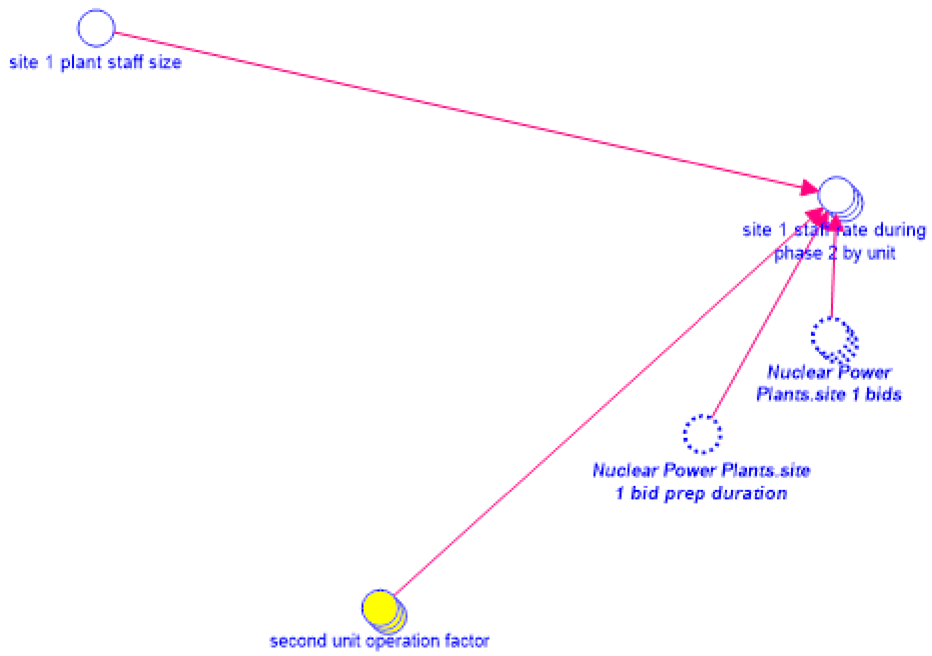

FIG. 26. Calculation of staffing rates during Phase 2. The calculation is done by NPP Unit.

A similar calculation is done for Phase 3 (Licence review and construction) of site 1 as shown in Fig. 27. In this case the overall staffing rate, ***site 1 staffing rate during phase 3*** is

(site_1_plant_staff_size*(Nuclear_Power_Plants.site_1_units_under_construction+Nuclear_Power_Plants.site_1_units_license)*second_unit_operation_factor/(Nuclear_Power_Plants.site_1_construction_time+Nuclear_Power_Plants.site_1_license_review_time))*DT

As was done for Phase 2, this calculation is done by NPP unit as if the entire staff were hired during Phase 3. This calculation is repeated for site 2.

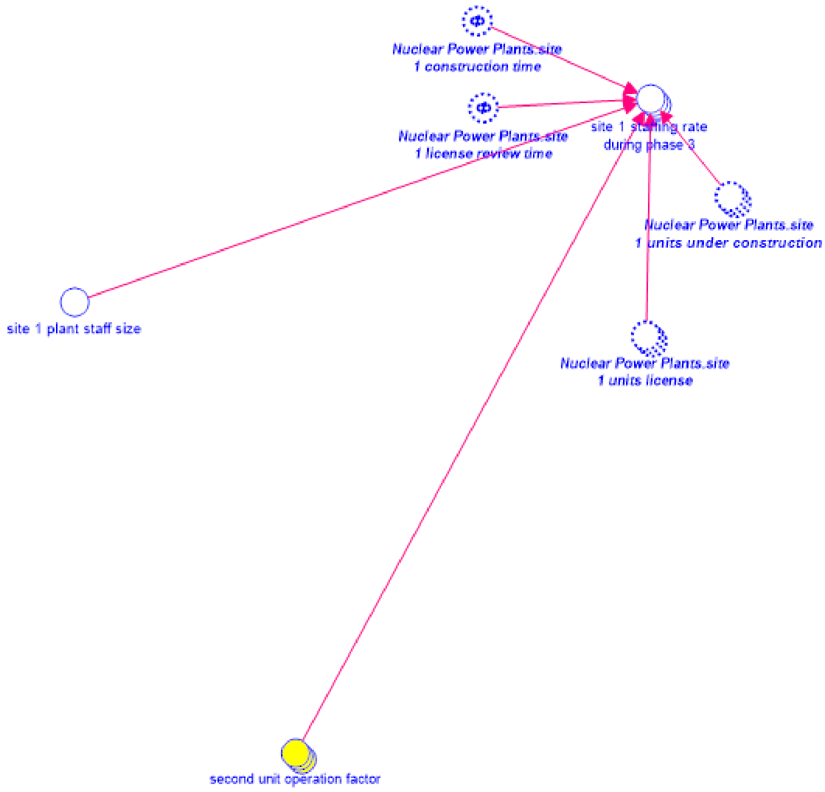

FIG. 27. Calculation of staffing rates during Phase 3 (calculation is done by NPP Unit).

The overall hiring rates during Phase 2 and Phase 3 are done by NPP Unit. However, the workforce calculation is done by skill area and accounts for different hiring rates by skill area and phase. The division of the operation staff is defined by the percentages of each skill level (manager, professional, technician, skilled craft, and semi-skilled) in the converter ***skill area fractions***. The fractions of staff with each skill level hired during each phase are in the converters ***license hiring fraction*** and ***construction hiring fraction***.

To maintain the user functionality for varying the timing for each unit individually, the reactor unit identification is to be maintained as the skill area and phasing factors are applied. An elegant but cryptic approach would be to create a two-dimensional transformation array with four reactor units by five skill levels. The less elegant but graphically impressive approach is to explicitly calculate the staffing curve for each reactor unit. The calculation requires seven factors as shown in Fig. 28. The factors ***Nuclear Power Plants.site 1 units license*** and ***Nuclear Power Plants.site 1 units under construction*** are used to select the correct hiring fraction and to apply the factors over the proper time intervals.

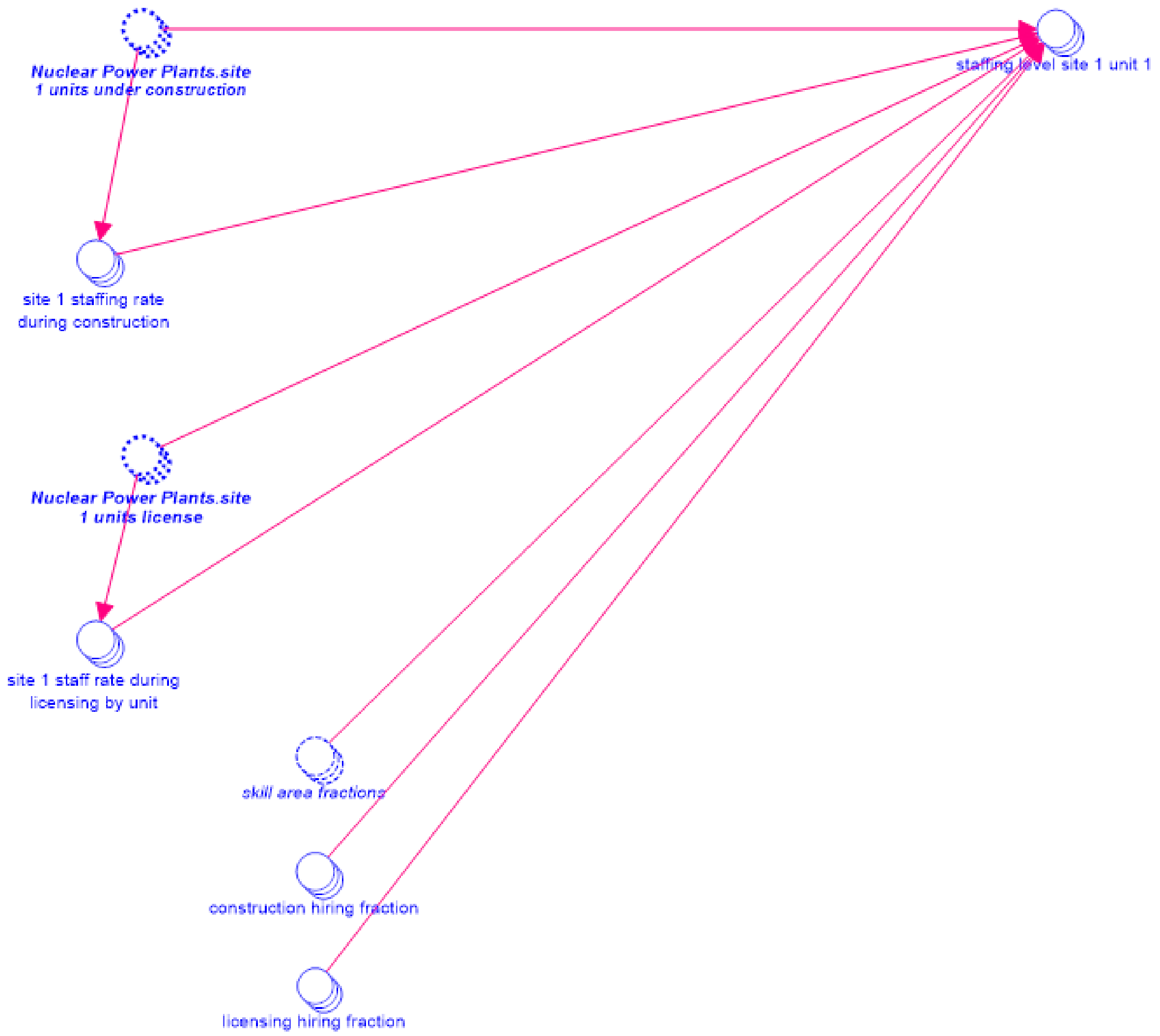

FIG. 28. Calculation of staffing requirement curve by phase for one unit.

This calculation is repeated for all eight units, then summed in ***staff required for new plants*** (the screenshot can be found under the NIDS Interactive Platform). ***Staff required for new plants*** is the value that is used as the year-by-year requirement for staffing levels by skill level for new NPPs. Note that this formulation loses the ability to identify the staff for a specific unit.

VI.3. DATA

Factors in the model that contain constants are shaded yellow. For the new plant staff calculation, there are only a few constants as identified in the Table 9.

TABLE 9. NEW PLANT STAFF DATA

No.	Variable	Description
1	phase_2_hiring_fraction	Fraction of workers in the operating organization that are hired during Phase 2 (See Ref. [1])

2	phase_3_hiring_fraction	Fraction of workers in the operating organization that are hired during the construction phase (Phase 3)
3	reference_staff_size	Total workers in the operating organization for each type of NPP
4	second_unit_operation_factor	The fraction of a single-unit NPP operating staff that would be required for a two-unit plant. Unit 2 is treated as a second unit with unit 1, unit 4 is treated as a second unit with unit 3

The hiring fractions are found in the *Start Up* tab of the data file. Second unit operation factor is calculated in the staffing tab. The reference staff size are default values by reactor type that are set in the input data tab of the data file.

APPENDIX VII.
OPERATING STAFF CALCULATIONS

VII.1. INTRODUCTION

This section of the NPHR modelling tool calculates the staffing requirements by skill level for the operating organization accounting for contracting approaches and outsourcing. The staffing requirements during Phase 2 and Phase 3 are part of this calculation: see Appendix VI.

VII.2. CHANGES TO THE MODEL FOR OPERATING STAFF

The operating staff model was based on an example provided in the Appendix of Nuclear Power Plant Organization and Staffing for Improved Performance: Lessons Learned, IAEA TECDOC No. 1052 [7] with typical startup curves. This approach did not represent multi-unit NPPs well. It also assumed all NPPs in the model were staffed in an identical fashion.

The NPHR V3.0 for operating staff has been substantially modified to:

- Show single unit and two-unit NPPs;
- Allow second-site NPPs to have a different operating staff model;
- Include representation of recruiting strategies from all potential sources of labour.

In addition, the previous model was inconsistent on how it handled the replacement of staff leaving the operating organization and how it handled staff for new NPPs. This inconsistency has been corrected to give a better approach to recruitment.

VII.3. OPERATING STAFF MODEL

The operating organization staffing model is based on comparing the current staff level to the required staff level and recruiting workers to fill the gap. The current staffing level includes the staff in the operating organization employed by the owner/operator, contracted to the owner/operator, provided by the vendor, and those hired and in training. The required staffing is determined from the staffing level required for operating plants and the staff required for new NPPs which varies with time (See Appendix VI).

A challenge for modelling operating staff is representing the workforce structure. The workforce in general is described by education level and degree areas. The workforce for the operating organization is organized around process areas. The model for recruiting has to provide the translation between these structures.

Since the purpose of the model is to reflect the national strategy, the model has to reflect contracting arrangements and approaches to workforce management. Contracting arrangements include the following contractual approaches with the vendor:

- BOO: The vendor is responsible for all staff for construction and operation. In this approach it is assumed that the workforce comes primarily from the vendor country;
- BOOT: This approach is the same as BOO except that the responsibility for operations reverts to the host country over some period after commissioning and the workforce gradually transitions to the domestic workforce;
- Turnkey: The host country is responsible for all operating staff from commissioning onwards;
- Custom: The model allows the user to develop additional options for sharing responsibility between the owner/operator and the vendor by NPP function.

Workforce management includes approaches to outsourcing. Outsourcing means that NPP staff may work at the NPP but are provided by an external organization rather than being an employee of the operating company. A secondary consideration is the source of the outsourced staff, whether they come from the domestic workforce or are recruited from outside the country.

VII.4. TECHNICAL DETAILS

The reference operating staff model for a single-unit NPP can be found in the Appendix of Nuclear Power Plant Organization and Staffing for Improved Performance: Lessons Learned [4]. In the first version of the NPHR modelling tool, this was combined with an operations structure and skill level analysis to create a workforce structure. The time phasing of staff for new NPPs was taken from the standard startup curve shown in Fig. 29, where three versions of this curve are compared.

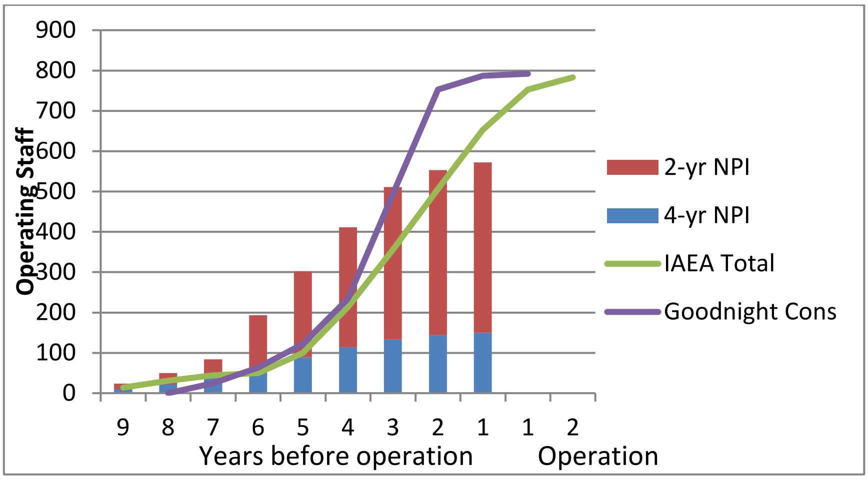

FIG. 29. Three versions representing staffing Prior to NPP startup.

NPHR V3.0 uses the modified staffing model found in Appendix I of Workforce Planning document [2] which gives examples of NPP staffing numbers by function for both single-unit and two-unit NPPs. In the NPHR data file, Staffing Tab, Columns CE-CG, these data are used to calculate staffing for seven process areas for a single-unit plant. For a two-unit plant, multipliers for the staffing of each process area are calculated.

The model for demand for operating staff is found in the *Workforce Calculations* sector of the *Workforce* module in the NPHR modelling tool. The calculations at the top of the sector compare the current workforce to the required workforce (the screenshot from the NPHR modelling tool is available at the NIDS Interactive Platform). On the left, the current staffing working for the owner/operator or the vendor is summed by skill level. Included in this sum are operating staff during the transition to decommissioning. On the right side is the calculation of staffing requirements for new plants during Phase 2 and Phase 3 and currently operating NPPs. These values are compared in the converter ***operating workforce needed***, which also considers the transition to decommissioning. The calculation of staffing for new NPPs in Phase 2 and Phase 3 is described in the document NPHR V3.0 Staffing for New NPP under the NIDS Interactive Platform folders.

All the detailed calculations and explanations are available in the attachment to NPHR V3.0 Staffing for New NPP under the NIDS Interactive Platform.

VII.5. DATA

Factors in the model that contain constants are shaded yellow. Data for the operating staff calculation are listed in the Table 10. These data can be found in the Vendor Contract tab of the data file and the user may select between contracting strategies while running the model. Likewise, the timing factors for BOOT contracts may be adjusted in the interface. The recruiting strategy factors are set in the *Input Data* tab and can be modified in the interface when the model is running.

TABLE 10. DATA FOR THE OPERATING STAFF CALCULATION

No.	Variable	Description
1	contracting_BOO	Decimal fraction of each process area to be staffed by the vendor under a BOO arrangement
2	contracting_BOOT	Decimal fraction of each process area to be staffed by the vendor under a BOOT arrangement
3	contracting_Turnkey	Decimal fraction of each process area to be staffed by the vendor under a Turnkey arrangement
4	contracting_USER_1	Decimal fraction of each process area to be staffed by the vendor under a contracting arrangement defined by the user
5	contracting_USER_2	Decimal fraction of each process area to be staffed by the vendor under a contracting arrangement defined by the user
6	prof_recruiting_strategy	Target decimal fraction of professional degreed workers to be recruited from each workforce segment
7	tech_recruiting_strategy	Target decimal fraction of technicians to be recruited from each workforce segment
8	craft_recruiting_strategy	Target decimal fraction of craft skill workers to be recruited from each workforce segment
9	BOOT_transition_time	Number of years for operations to transition from vendor to a domestic organization
10	BOOT_delay	Number of years following NPP startup that operations begins to transition from the vendor to a domestic organization
11	skill_area_fractions	Decimal fraction of operating staff in each skill level: manager, semi-skilled, skilled craft, technician, and professional
12	process_area_fractions	Decimal fraction of all workers in the operating organization that work in each process area

In addition, there are two modules in the operating staff calculation section of the model that also contain data imported from the data file. The modules are *Initial Workforce Calculations*, which calculates the starting staff levels if there are existing NPPs, and *Outsourcing*, which selects an outsourcing strategy and provides factors to the staffing requirements. The initial age fractions are selected in the *AgeDistribution* tab and the outsourcing factors are defined in the *Outsourcing* tab. The data in these modules is presented in Table 11:

TABLE 11. DATA FOR INITIAL WORKFORCE CALCULATIONS AND OUTSOURCING

No.	Variable	Description
1	initial_workforce_age_fractions	Decimal fraction of all workers in each five-year age bin at the start of the simulation
2	Standard_Outsourcing_Fractions	Decimal fraction of workers employed in operating the NPP in each process area that are provided by an outside contractor
3	Agressive_Outsourcing_Fractions	Decimal fraction of workers employed in operating the NPP in each process area that are provided by an outside contractor
4	Euro_1_Outsourcing_Fractions	Decimal fraction of workers employed in operating the NPP in each process area that are provided by an outside contractor
5	Euro_2_Outsourcing_Fractions	Decimal fraction of workers employed in operating the NPP in each process area that are provided by an outside contractor
6	User_Defined_Fractions	Decimal fraction of workers employed in operating the NPP in each process area that are provided by an outside contractor – defined by the user

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[6] Nuclear Power Plant Construction Infrastructure Assessment, Rev. 0, MPR-2776, Department of Energy, Washington (2005)

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Power Plant Organization and Staffing for Improved Performance: Lessons Learned, IAEA-TECDOC-1052, IAEA, Vienna (1998).

LIST OF ABBREVIATIONS

BOO	Build-Own-Operate
BOOT	Build-Own-Operate-Transfer
BLS	US Bureau of Labor Statistics
D&D	Decontamination and Decommissioning
EPC	Engineering, Procurement and Construction
HPC	Hinkley Point C
NPHR	Nuclear Power Human Resource
NPP	Nuclear Power Plant
TSO	Technical Support Organisation

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