European Commission

JRC SCIENCE FOR POLICY REPORT

Top-Down Workforce Demand from Energy Scenarios: Alternative Demand Scenarios

EHRO-N Report

Ferry Roelofs
Massimo Flore

2016

Joint Research Centre

European Commission
Joint Research Centre
Knowledge for Nuclear Safety, Security and Safeguards

JRC Science Hub
https://ec.europa.eu/jrc

EHRO-N website
http://ehron.jrc.ec.europa.eu

JRC105036

Abstract
In all previous analyses, the so-called '20% nuclear electricity' (officially called 'Delayed CCS') scenario of the EC Energy Roadmap 2050 was applied to determine the HR requirements. This scenario was selected because it leads to the highest penetration of nuclear energy and will therefore be most demanding for the assessment of HR requirements. However, over the past years, this rather optimistic scenario for nuclear energy demand was often questioned. Therefore, it was decided to study the effect of less demanding alternative scenarios. For consistency, it was decided to extract both alternatives from the same EC Energy Roadmap 2050 report. However, the two alternative scenarios result in completely different shares of nuclear, both significantly less than the reference '20% nuclear' scenario. The first alternative scenario is the so-called 'energy efficiency' scenario. Within this scenario, obviously, the emphasis is put on efficient use of energy. The resulting energy demand scenario leads to a relative high penetration of renewables but also still a significant share of nuclear. Within the so-called 'low nuclear' scenario, the main assumption is that public acceptance of nuclear is extremely low. This means that new build projects which are in the planning are cancelled.

Top-Down Workforce Demand from Energy Scenarios: Alternative Demand Scenarios

Ferry Roelofs
Nuclear Research and Consultancy Group

Massimo Flore
European Commission, Joint Research Centre
Knowledge for Nuclear Safety, Security and Safeguards

This page was left blank intentionally

Contents

Summary

EHRO-N provides the European Commission (EC) with essential data related to supply and demand for nuclear experts in the EU28 and the enlargement and integration countries based on bottom-up information from the nuclear industry. The objective is to assess how the supply of experts for the nuclear industry in the EU28 and the enlargement and integration countries responds to the needs for the same experts for the present and future nuclear projects in the region. Complementary to the bottom-up approach taken by the EHRO-N team at JRC, a top-down modelling approach has been taken by Roelofs and Von Estorff (2013). In follow-up, Roelofs and Von Estorff (2014) took a similar top-down approach to determine the influence of long term operation (LTO) on the HR requirements in the EU28 and enlargement and integration countries. This work was followed by a sensitivity analysis reported by Roelofs & Flore (2016).

In all previous analyses, the so-called '20% nuclear electricity' (officially called 'Delayed CCS') scenario of the EC Energy Roadmap 2050 was applied to determine the HR requirements. This scenario was selected because it leads to the highest penetration of nuclear energy and will therefore be most demanding for the assessment of HR requirements. However, over the past years, this rather optimistic scenario for nuclear energy demand was often questioned. Therefore, it was decided to study the effect of less demanding alternative scenarios. For consistency, it was decided to extract both alternatives from the same EC Energy Roadmap 2050 report. However, the two alternative scenarios result in completely different shares of nuclear, both significantly less than the reference '20% nuclear' scenario. The first alternative scenario is the so-called 'energy efficiency' scenario. Within this scenario, obviously, the emphasis is put on efficient use of energy. The resulting energy demand scenario leads to a relative high penetration of renewables but also still a significant share of nuclear. Within the so-called 'low nuclear' scenario, the main assumption is that public acceptance of nuclear is extremely low. This means that new build projects which are in the planning are cancelled. The following main conclusions are drawn from the analysis:

- The reference '20% nuclear' scenario shows a peak workforce for operation and construction of nuclear power plants around 2040 of about 120 000 fte and eventually leads to a workforce in 2050 of about 60 000 fte which is only slightly lower than the current workforce mainly due to the fact that the future reactors to be operated are larger and require less workforce per MWe.
- The 'energy efficiency' scenario leads to gap in construction from current construction to 2030. After that, the peak HR requirements for construction will be at the same level as in the reference '20% nuclear' scenario, i.e. about 50 000 fte. In 2050, the workforce for operation and construction of nuclear power plants is still significant and adds up to about 45 000 fte.
- The 'low nuclear' scenario leads to no construction after the reactors currently under construction and to a gradual decline of nuclear operational workforce. In 2050, the workforce is declined to a level of about 15 000 fte.

1 Introduction

EHRO-N or the European Human Resource Observatory for the Nuclear Energy Sector has the task to build a system for monitoring the supply of and demand for experts needed for the nuclear energy sector in the 28 European member states (EU28) and the enlargement and integration countries for the years to come until 2020. EHRO-N provides the European Commission (EC) with essential data related to supply and demand for nuclear experts in the EU28 and the enlargement and integration countries based on bottom-up information from the nuclear industry. The objective is to assess how the supply of experts for the nuclear industry in the EU28 and the enlargement and integration countries responds to the needs for the same experts for the present and future nuclear projects in the region.

The data is based on an analysis of responses of surveys that are sent to higher education institutions in EU28 and the enlargement and integration countries that offer nuclear-related degrees, and to nuclear stakeholders, who are active on the EU-28 and the enlargement and integration countries nuclear energy labor market. The quantitative data received is quality checked against a quality assurance procedure set within the Senior Advisory Group (SAG) of EHRO-N. Additionally, the EHRO-N data is assessed against data available from other sources (e.g. IAEA data, national nuclear human resource reports, if available). Besides the bottom-up approach taken by the EHRO-N team, an alternative top-down modeling approach was undertaken by Roelofs and Von Estorff (2013 & 2014), followed by a sensitivity analysis reported by Roelofs & Flore (2016).

In all previous analyses, the so-called '20% nuclear electricity' (officially called 'Delayed CCS') scenario of the EC Energy Roadmap 2050 was applied to determine the HR requirements. This scenario was selected because it leads to the highest penetration of nuclear energy and will therefore be most demanding for the assessment of HR requirements. However, over the past years, this rather optimistic scenario for nuclear energy demand was often questioned. Therefore, it was decided to study the effect of less demanding alternative scenarios.

In chapter 2, the computational tool which serves as a base for the current analysis is introduced. After that, chapters 3 through 5 describe the input for the analysis. Chapter 3 describes the applied nuclear energy demand scenario. Chapter 4 shows the current reactor park and the assumptions taken for new reactors to be constructed. Chapter 5 explains the applied workforce models developed for this top-down modelling approach and the associated age profile as derived from the bottom-up EHRO-N survey. Chapter 6 contains the results of the analyses for the determination of the HR requirements for the various alternative energy demand scenarios. Finally, chapter 7 summarizes the conclusions.

2 DANESS Analysis Tool

2.1 DANESS Description

To assess the impacts of nuclear new build scenarios, the DANESS code ("Dynamic Analysis of Nuclear Energy System Strategies") version 4.0 (Van den Durpel et al., 2008) developed by Argonne National Laboratory has been used. DANESS simulates a reactor park and the corresponding flows of fuel, spent fuel, high and intermediate level waste as well as all intermediate stocks and fuel cycle facility throughput.

DANESS is a system dynamics model, and uses iThink-software (Isee Systems, 2009). DANESS simulates fuel cycles from uranium mining, reprocessing, to geological disposal. For any modeled combination of reactor types and fuel cycles DANESS projects electricity production cost, fuel mass flows, and waste quantities as a function of time, spanning periods from decades up to centuries.

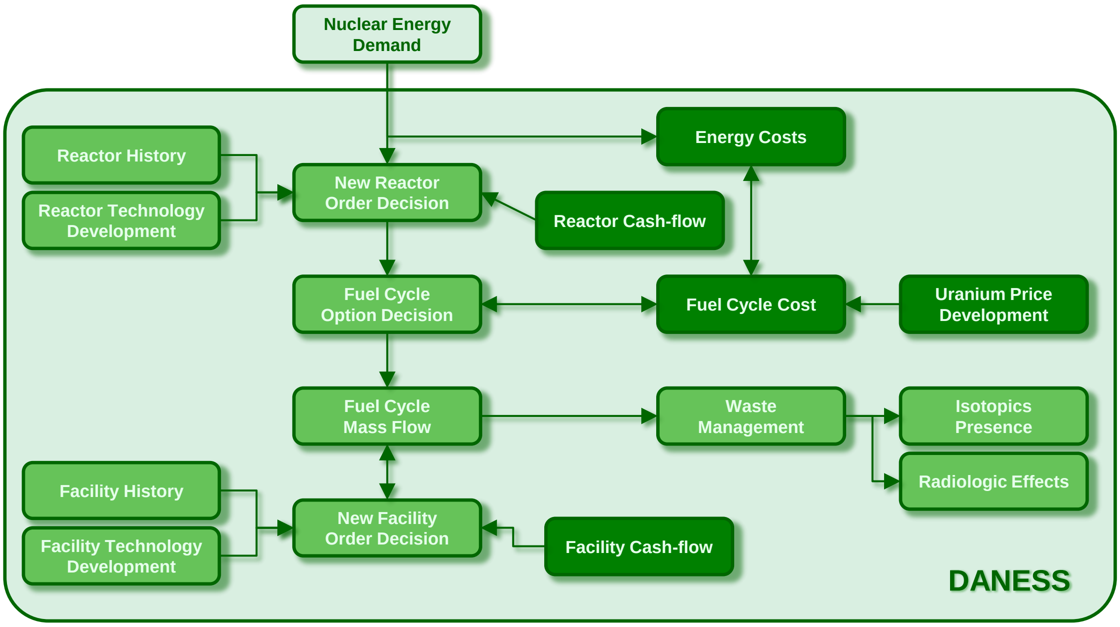

Figure 1: DANESS Fuel Cycle Functionality

New reactor types, characterized by techno-economic parameters representing their fuel consumption and overall effectiveness, are introduced based on the requirement to fulfill a certain scenario dependent nuclear energy demand. The technological readiness of reactors or fuel cycle facilities can be represented by means of delays in the availability of the technologies. Fuel cycle costs are calculated for each nuclear fuel input, and are combined with capital and O&M cost models to project electricity production cost per reactor type.

Figure 1 shows the full fuel cycle functionality implemented in the code.

2.2 Benchmarks and Verifications

A variety of benchmark and verification activities have been and are undertaken with DANESS within various international projects, e.g. IAEA-INPRO (2008), PUMA (2008), and Guérin et al. (2009). More benchmarking activities are reported in Van Den Durpel (2008). Within the MIT benchmark reported by Guérin et al. (2009), the focus was put on validation of material flows, uranium consumption, reprocessing, and storage. The results of the DANESS code were consistent with the results determined with the CAFCA code by MIT, the COSI code by CEA, and the VISION code by INL. Extensive benchmarking of the code was further performed within the framework of the European FP6 PUMA project (PUMA, 2008). Two benchmarks were performed within this framework in which also the ORION code by NNL and the OSIRIS code by AMEC were used. The focus in these benchmarks was put on the material flows, nuclide inventories, radiotoxicities, and decay heat. Where the results for material flows and nuclide inventories showed a good agreement, the results for radiotoxicities and decay heat showed deviations between the results of the different codes.

3 Nuclear Energy Demand Scenarios

In 2011, the European Commission (2011) issued the EC Energy Roadmap 2050. Within this roadmap, different scenarios are analyzed for the energy production in the EU27 countries. Their reference business as usual scenario leads amongst those scenarios to a high contribution from nuclear. However, the EU policy goal in emission reduction will not be realized. Amongst the other scenarios described in this report, the so-called ‘20% nuclear electricity’ (officially called ‘Delayed CCS’) scenario leads to the highest penetration of nuclear energy and will therefore be most demanding for the current assessment. Therefore, the ‘20% nuclear electricity’ scenario was selected for the workforce demand extrapolations reported in Roelofs & Von Estorff (2013, 2014) and Roelofs & Flore (2016). However, over the past years, this rather optimistic scenario for nuclear energy demand was often questioned, even though it is conservative with respect to the HR requirements, meaning it will put the largest demand on HR requirements.

Within the current report, the influence of two alternative energy demand scenarios is analyzed. For consistency, it was decided to extract both alternatives from the same EC Energy Roadmap 2050 report. However, two alternative scenarios result in completely different shares of nuclear, both significantly less than the reference 20% nuclear scenario. The first alternative scenario is the so-called energy efficiency scenario. Within this scenario, obviously, the emphasis is put on efficient use of energy. The resulting energy demand scenario leads to a relative high penetration of renewables but also still a significant share of nuclear. Within the so-called low nuclear scenario, the main assumption is that public acceptance of nuclear is extremely low. This means that new projects which are in the planning are cancelled.

As these nuclear energy demand scenarios were derived for the EU27 countries at that time, extrapolation to the current EU28 countries including the enlargement and integration countries is required. This has been achieved based on energy consumption figures around 2010 taken from CIA (2013). When this extrapolation is taken into account, the nuclear energy demand for the EU28 with enlargement and integration countries is about 16% higher than the demand for EU27 countries without enlargement and integration countries. Figure 2 shows the resulting nuclear energy demands for the period 2010-2050.

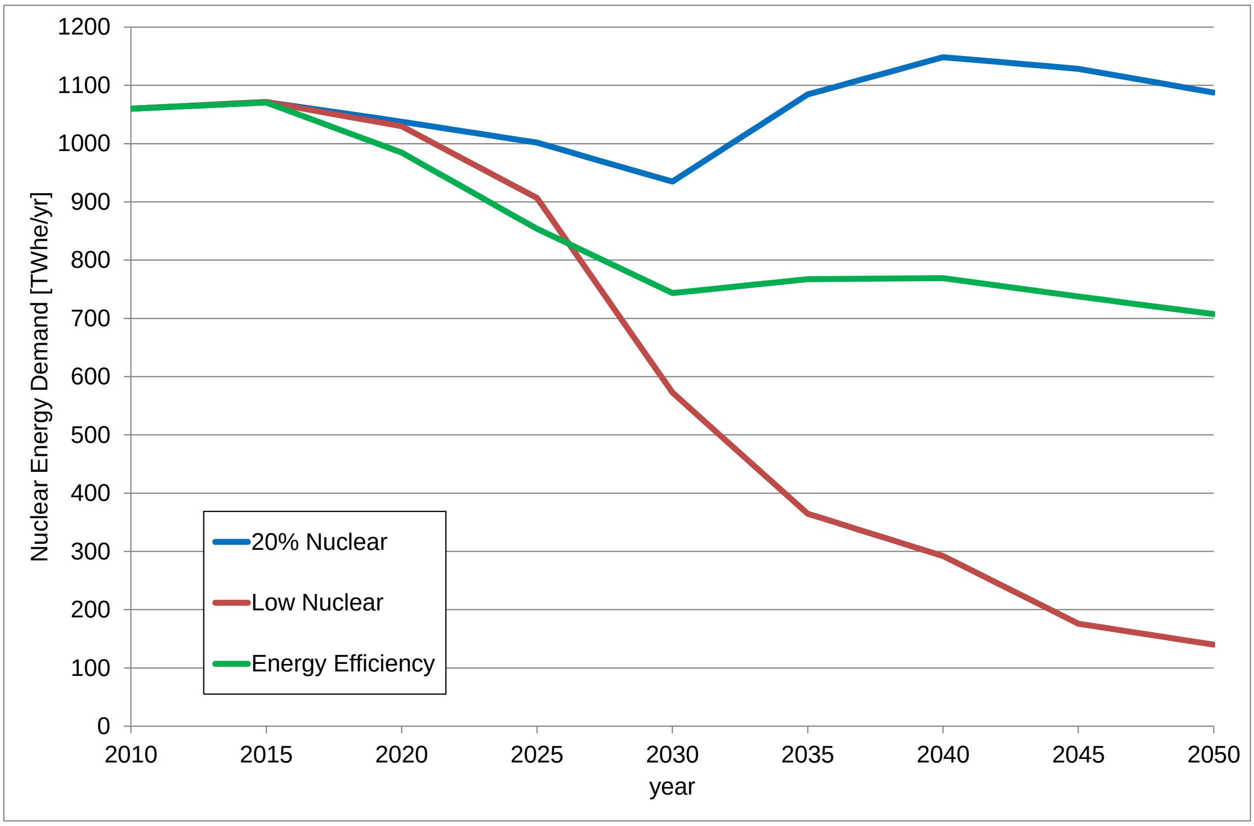

Figure 2: Nuclear Energy Demands based on the EC Energy Roadmap 2050 for EU28 countries including enlargement and integration countries

4 Reactor Park

4.1 Current Reactor Park

The current reactor park is modelled based on data retrieved from WNA (2014). This data was firstly used to model the existing reactor park. In addition, four reactors for which construction is ongoing were added to the current reactor park. These reactors are:

- Olkiluoto 3 in Finland,
- Flamanville 3 in France,
- Mochovce 3 & 4 in Slovakia.

Although it is known that there are plans to construct more nuclear reactors, these have not explicitly been taken in account. However, the DANESS model will implicitly take these into account when it determines new reactors to be constructed to balance the installed capacity with the nuclear energy demand.

The lifetime of the existing reactor park is determined from data provided by WNA (2014). Thus, this takes into account e.g. the post-Fukushima decisions in Germany, but also life-time extensions for nuclear reactors like in the Netherlands. After the lifetime of the existing reactor park was determined, also the lifetime extension resulting from possible long term operation is determined. In order to do so, the following assumptions were made:

- Lifetime extension is applied to individual reactors based on information provided by WNA (2014).
- Time horizon of lifetime extension
    - When not indicated differently, the lifetime of a reactor is extended to 60 years.
    - A lifetime of 50 years is assumed for
        - Advanced Gas-cooled Reactors in the UK
        - The Loviisa plant in Finland
        - The Paks plant in Hungary
        - The Kozloduy plant in Bulgaria
- No lifetime extension is assumed for:
    - reactors in Belgium
    - reactors in Germany
    - reactors in Switzerland
    - the Fessenheim plant in France
    - the magnox reactor in Wyllfa (UK)

Using this data, and in addition assuming that the EPR's under construction in Finland and France will have a 60 year lifetime and the two Slovakian reactors will have a 40 year lifetime, the shutdown profile of the current reactor park was determined and shown in figure 3.

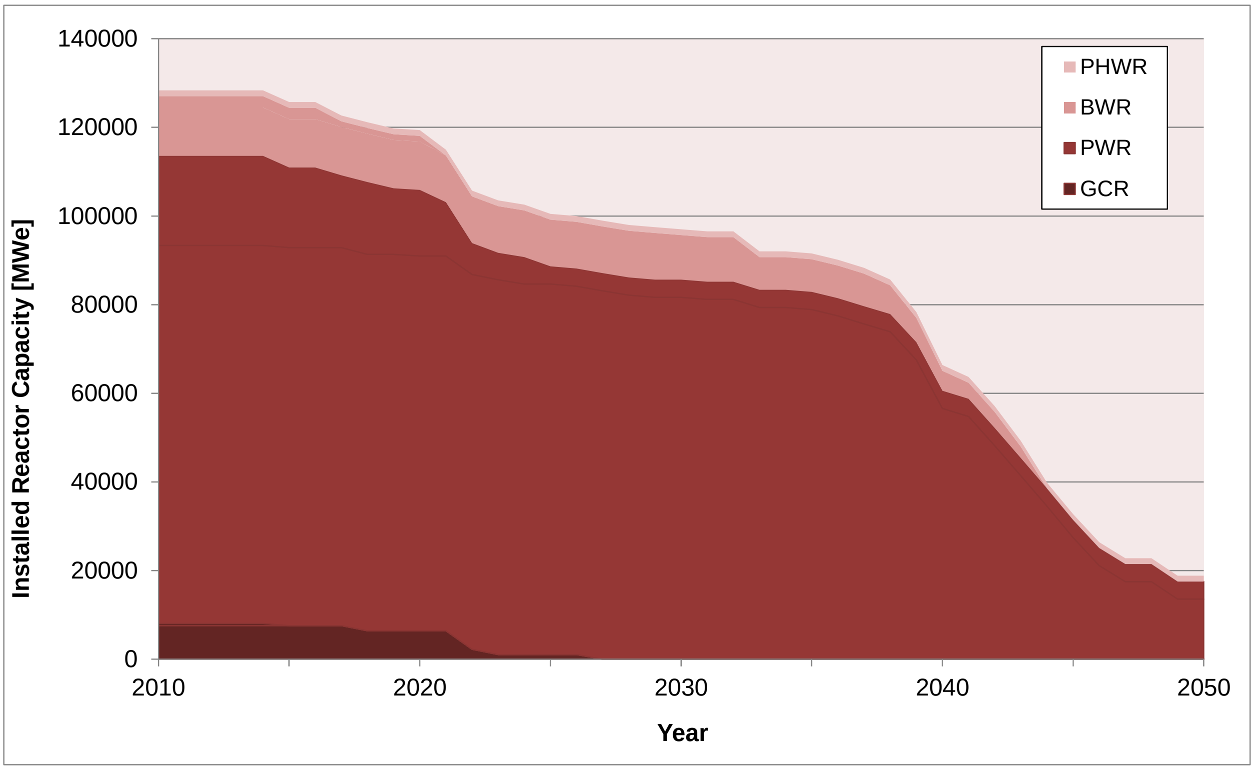

Figure 3: Shutdown profile (installed power) of the current reactor park under long term operation.

4.2 New Reactors

The reference reactor to be constructed is a generic 1400 MWe third generation nuclear reactor. The nuclear energy demand scenario described in chapter 3 is simulated assuming construction of only this type of generic reactor. An efficiency of 36%, a load factor of 80%, and a lifetime of 60 years are assumed. Table 1 summarizes the main characteristics of the reference generic nuclear reactor.

Table 1: Main characteristics of the generic third generation reactor

Reactor	Power [MWe]	Efficiency [%]	Load Factor [%]	Lifetime [yr]
Gen III LWR	1400	36	80	60

5 Workforce Models

5.1 Operations, Construction, and Long Term Operation

Within Roelofs & Von Estorff (2013, 2014), the workforce models for operation, construction, and long term operation of nuclear power plants have been described extensively, together with comparisons to actual reactor data. The modelled workforces are typically subdivided with respect to the data from the nuclear skills pyramid as presented by Simonovska & Von Estorff (2012) in figure 4. Apart from that, retirement profiles have been applied as reported by Roelofs & Von Estorff (2014).

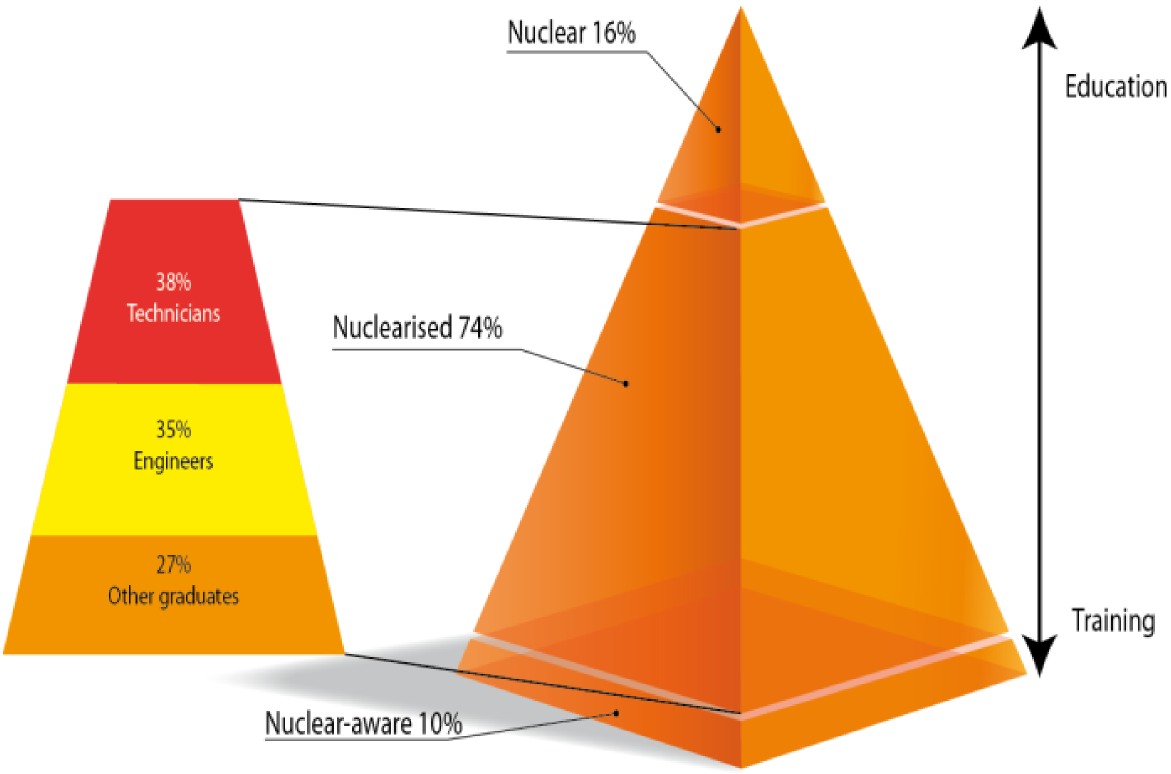

Figure 4: Nuclear Skills Pyramid (Simonovska & Von Estorff, 2012)

6 HR Requirements for Alternative Demand Scenarios

6.1 20% Nuclear Reference Scenario

The reactor park development under assumption of long term operation as outlined in chapter 4 is presented in figure 5. This reactor park development was already shown by Roelofs & Von Estorff (2014) and depends on the shutdown profile of the existing fleet and the selected nuclear energy demand scenario, in this case the 20% nuclear energy demand scenario from the EC Energy Roadmap 2050.

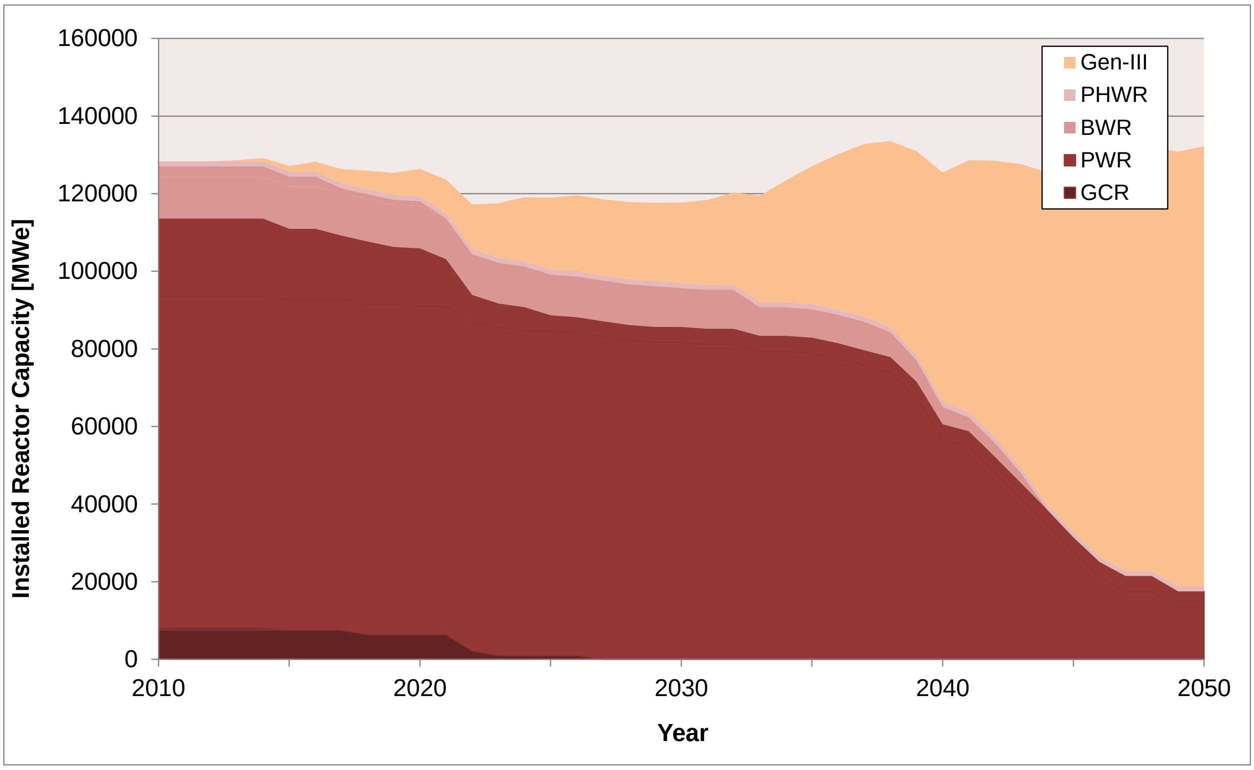

Figure 5: Reactor park development for the 20% nuclear demand scenario

Figure 6 provides the development of the HR requirements for the operation and construction of nuclear power plants under long term operation conditions. From this figure it is clear that these requirements may vary between 60 000 and 120 000 fte. Under the specific long term operation assumptions, the peak demand can be expected around 2040 when the existing fleet is being taken out of operation and a new fleet is under construction. Related to that, figure 7 shows the workforce for construction only, extracted from the data shown in figure 6. Here, the peak around 2040 is more pronounced.

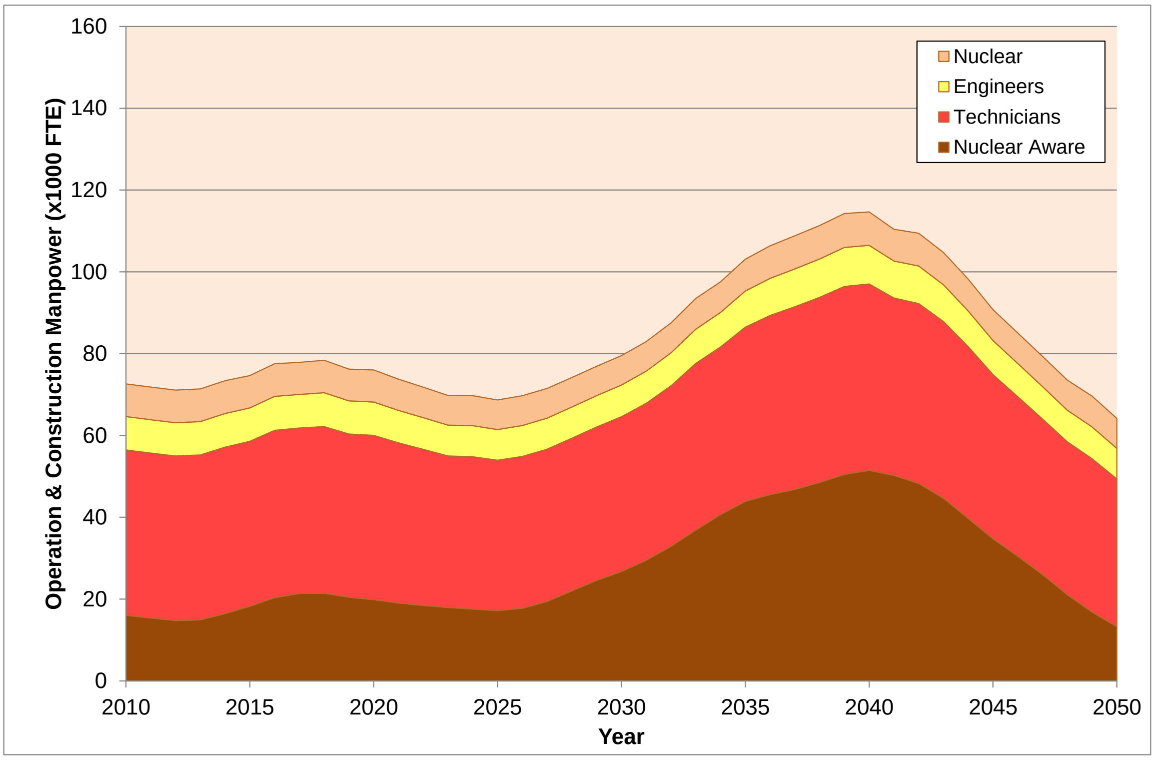

Figure 6: HR requirements for operation and construction of nuclear power plants in the 20% nuclear demand scenario.

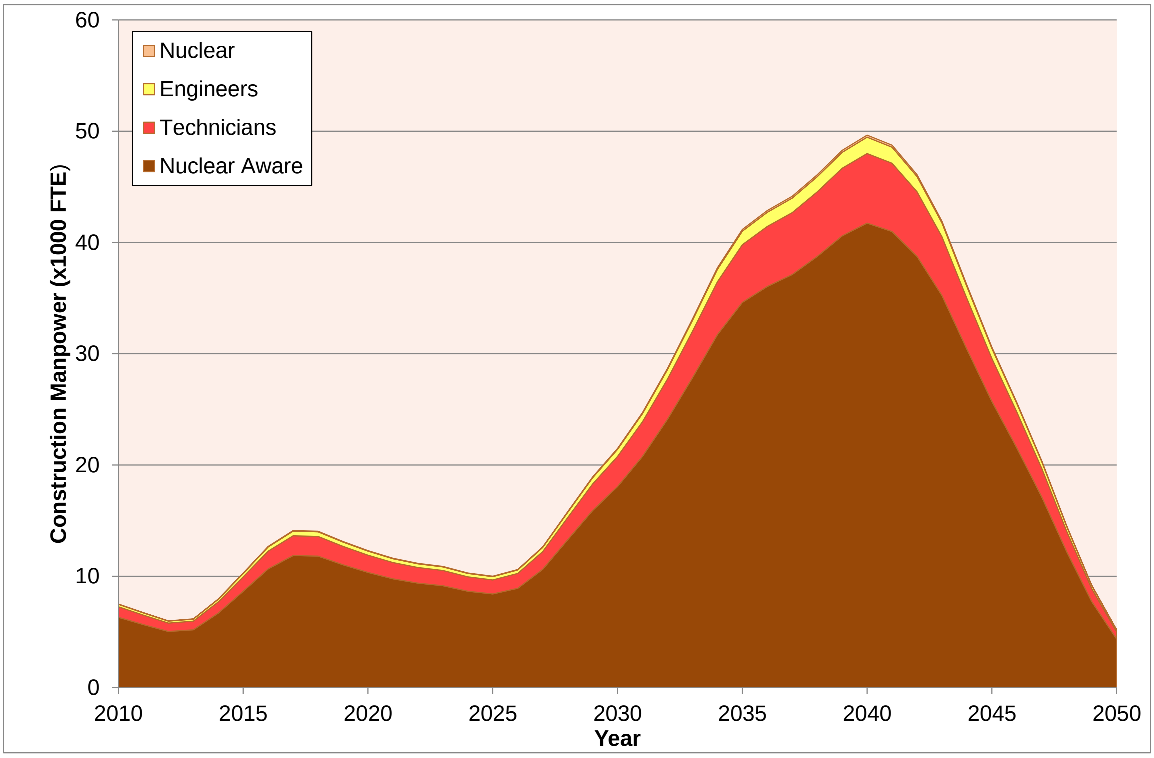

Figure 7: HR requirements for construction of nuclear power plants in the 20% nuclear demand scenario

6.2 Energy Efficiency Scenario

The energy efficiency scenario as shown in figure 2, clearly leads to less penetration of nuclear. The nuclear energy demand up to 2030 does not require additional Generation III nuclear plants to be constructed apart from the ones already under construction. Figure 8 shows that only around 2035, when the major part of the existing fleet is taken out of operation, a relatively small amount of new nuclear reactors needs to be constucted to keep up with the foreseen nuclear energy demand.

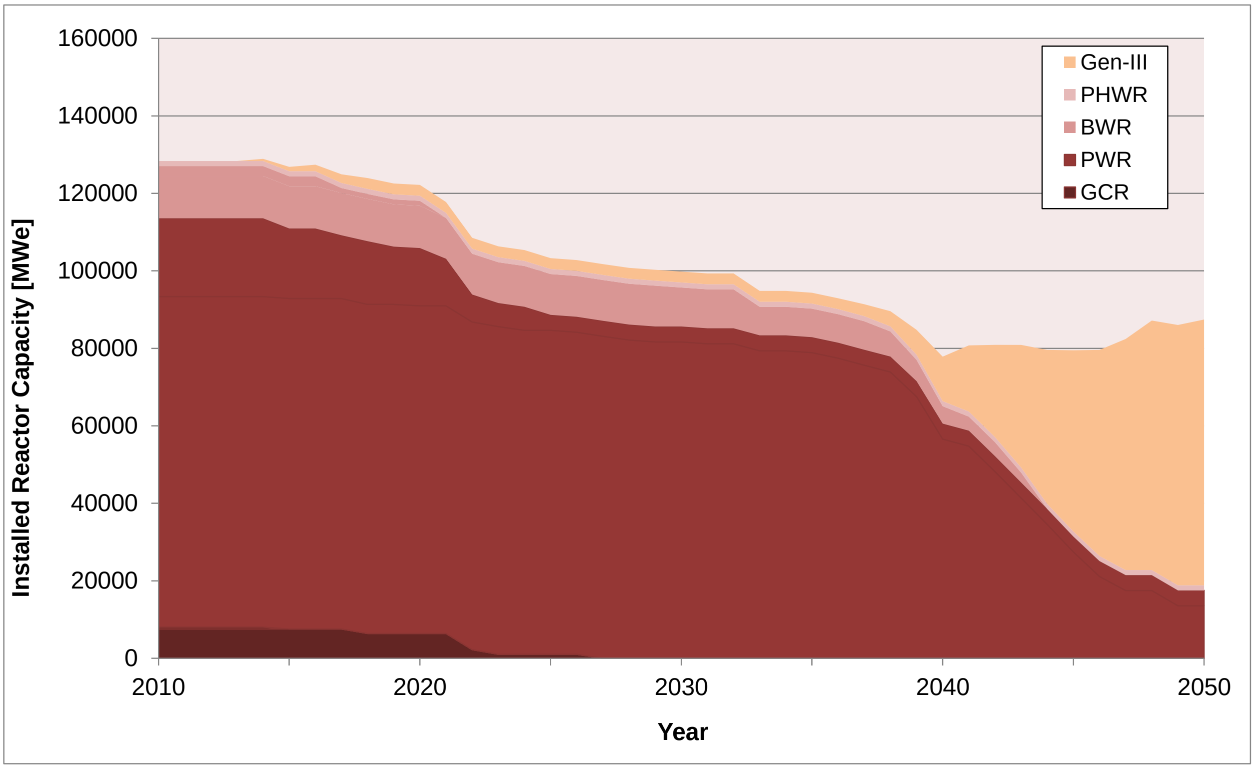

Figure 8: Reactor park development for the energy efficiency demand scenario

Figure 9 shows the workforce for operation and construction of nuclear power plants. After a slow decline in, mainly, operational personel, the short wave of new build adds up to the HR requirements around 2040. After this, the number further decline slowly. Again this is even more pronounced visible in figure 10 which only shows the workforce for construction. After the power plants currently under construction, for a period of about 10 years a gap in construction will occur. Only around 2030, the construction of a new fleet will start leading to a sudden increase in HR requirements for construction.

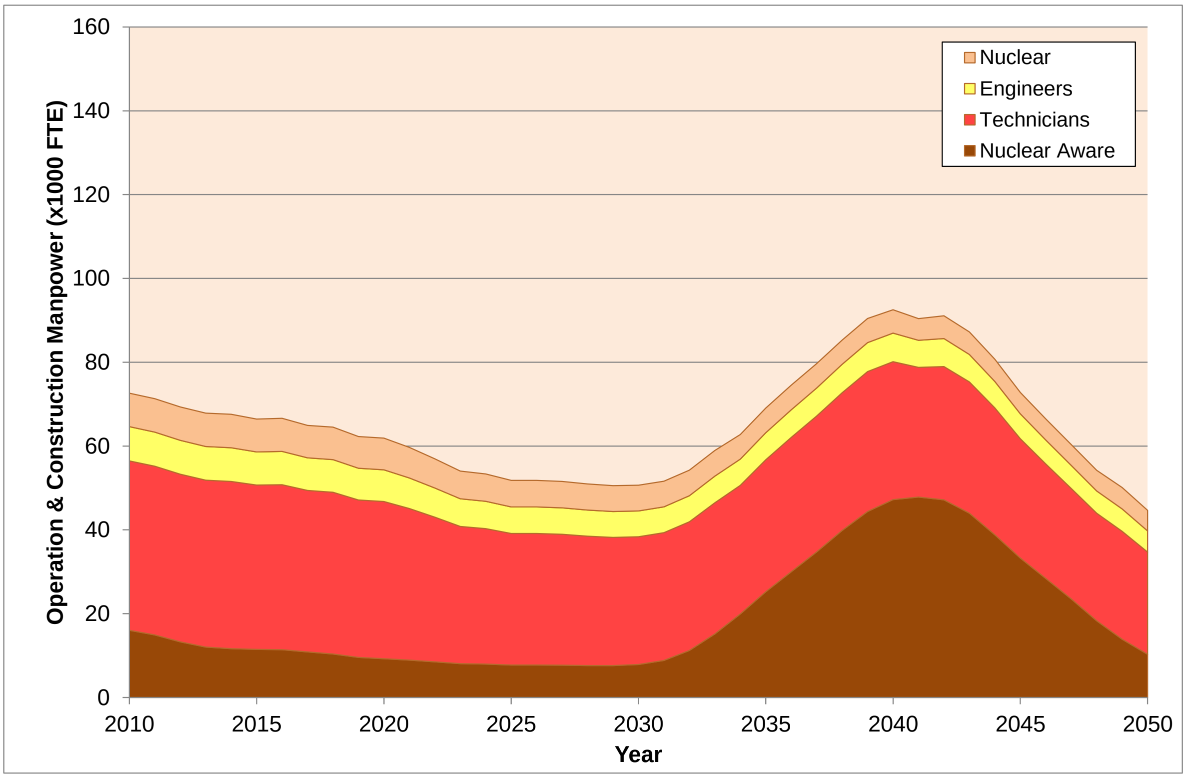

Figure 9: HR requirements for operation and construction of nuclear power plants in the energy efficiency demand scenario.

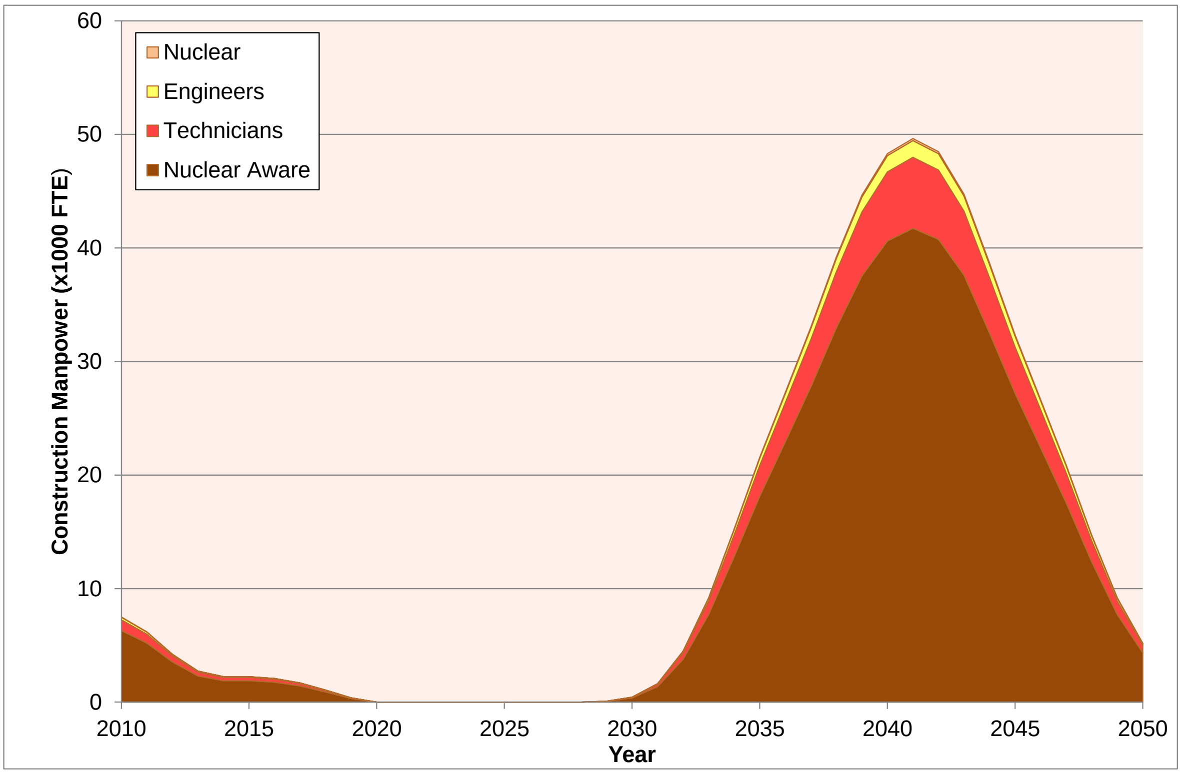

Figure 10: HR requirements for construction of nuclear power plants in the energy efficiency demand scenario.

6.3 Low Nuclear Scenario

The low nuclear scenario is in fact a face out scenario. After the reactors currently under construction, no new reactors will be build. This is clearly visible in figure 11 which shows the reactor park development of this scenario.

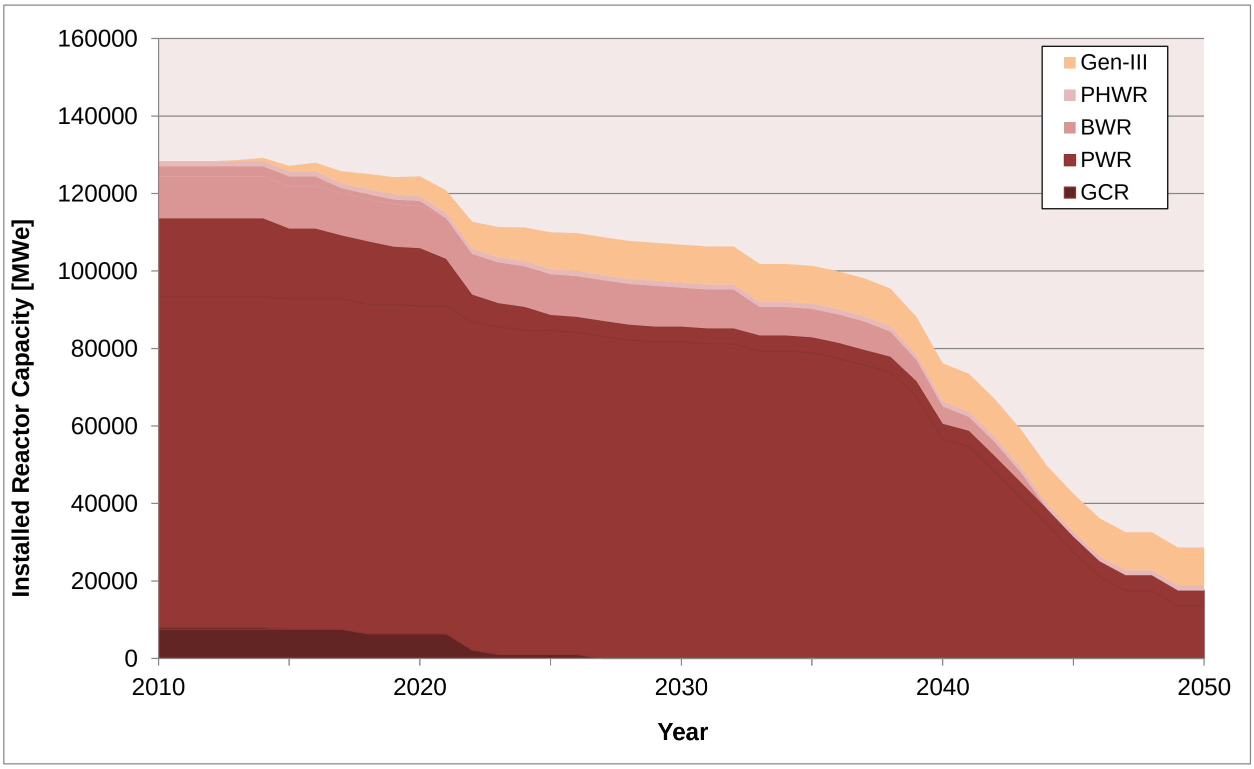

Figure 11: Reactor park development for the low nuclear demand scenario.

Figure 12 obviously shows a constant decline in the workforce for operation and construction of nuclear power plants. In fact, in 2050 only a small remainder of nuclear power plants will still be in operation. Figure 13 again emphasizes that only the reactors currently under construction will be finished and that after that, no nuclear new build will be done. Therefore, the workforce for construction will vanish after the reactors currently under construction have been finished.

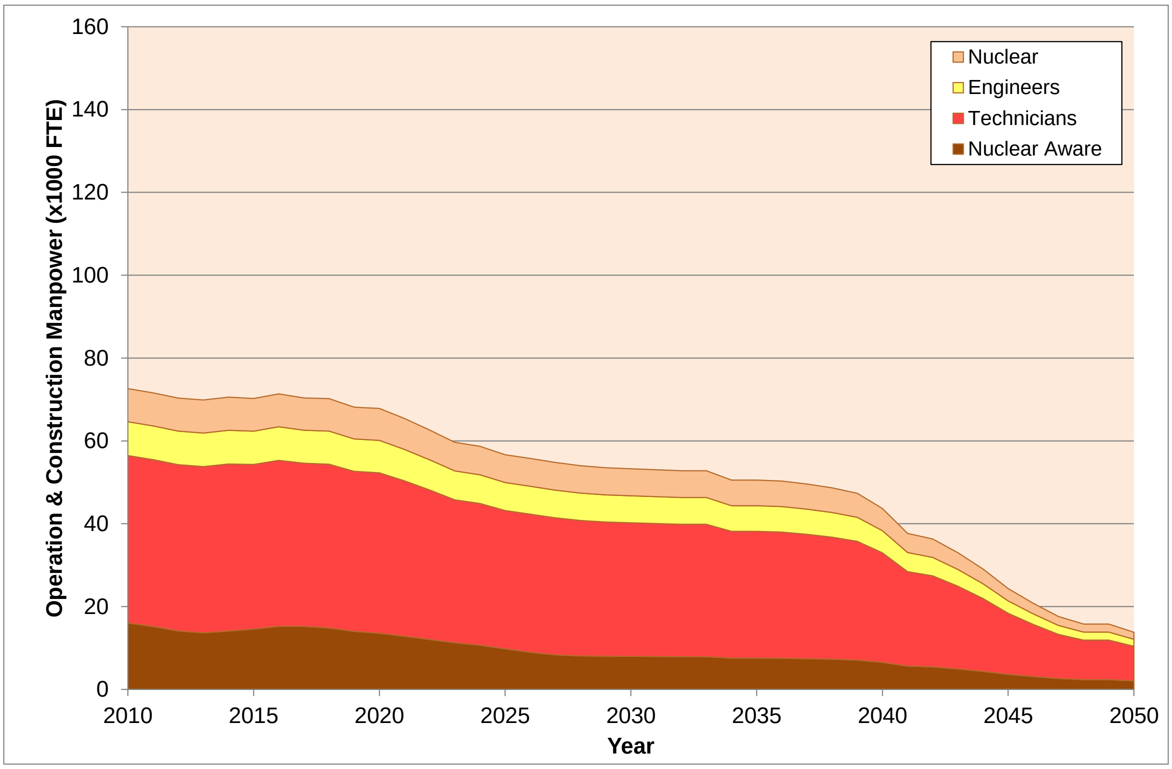

Figure 12: HR requirements for operation and construction of nuclear power plants in the low nuclear demand scenario.

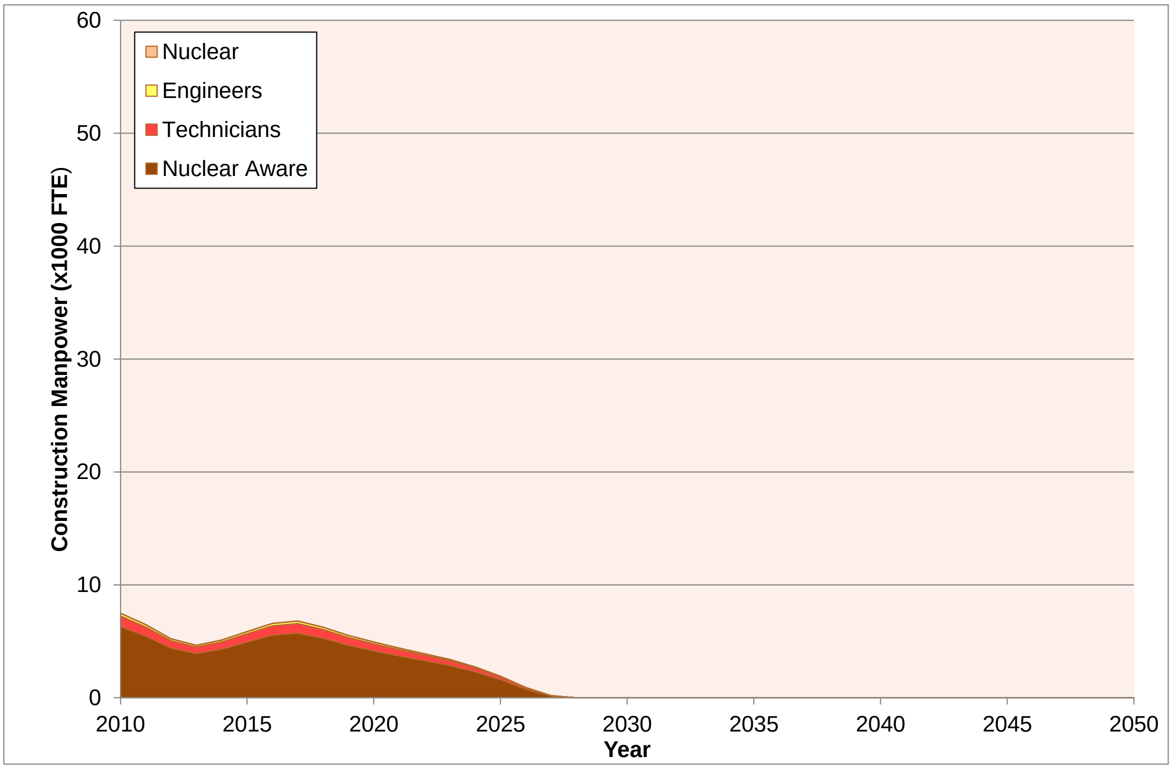

Figure 13: HR requirements for construction of nuclear power plants in the low nuclear demand scenario.

7 Conclusions

This report describes the results of the top down workforce modelling of HR requirements for alternative energy demand scenarios up to 2050. The following main conclusion are drawn from the analysis:

- The reference ‘20% nuclear’ scenario shows a peak workforce for operation and construction of nuclear power plants around 2040 of about 120 000 fte and eventually leads to a workforce in 2050 of about 60 000 fte which is only slightly lower than the current workforce mainly due to the fact that the future reactors to be operated are larger and require less workforce per MWe.
- The ‘energy efficiency’ scenario leads to gap in construction from current construction to 2030. After that, the peak HR requirements for construction will be at the same level as in the reference ‘20% nuclear’ scenario, i.e. about 50 000 fte. In 2050, the workforce for operation and construction of nuclear power plants is still significant and adds up to about 45 000 fte.
- The ‘low nuclear’ scenario leads to no construction after the reactors currently under construction and to a gradual decline of nuclear operational workforce. In 2050, the workforce is declined to a level of about 15 000 fte.

8 References

Brancucci R., Flore M., Von Estorff U., 2014. Post-Fukushima Analysis of HR Supply and Demand. JRC92404, EUR 27017 EN, Petten, Netherlands, available on ehron.jrc.ec.europa.eu.

CIA, 2013. The World Factbook: Country Comparison – Electricity Consumption. https://www.cia.gov/library/publications/the-world-factbook/rankorder/2042rank.html, accessed February 2013.

Deffrennes M., Gress P., 2012. Socio-Economic Role of Nuclear Energy to Growth and Jobs in the EU for time Horizon 2020-2050. RM 2050 - Nuclear Energy 2050 - Growth and Jobs.

European Commission (2011). Energy Roadmap 2050. COM(2011) 885/2, Brussels, Belgium

Guérin L., Feng B., Hejzlar P., Forget B., Kazimi M., Van Den Durpel L., Dixon B., Matthern G., Boucher L., Delpech M., Girieud R., Meyer M., 2009. A Benchmark Study of Computer Codes for System Analysis of the Nuclear Fuel Cycle. MIT-NFC-TR-105, Boston, USA.

IseeSystems, 2009. iThink software, www.iseesystems.com.

PUMA, 2008. European Commission 6th Framework Programme Project Plutonium and Minor Actinides Management in Thermal High Temperature Reactors. www.puma-project.eu.

Roelofs F., Flore M., 2016. Top Down Workforce Demand from Energy Scenarios: Sensitivity Analysis. JRC, in press, Petten, Netherlands, to be available on ehron.jrc.ec.europa.eu.

Roelofs F., Von Estorff U., 2013. Top-down workforce demand extrapolation from nuclear energy scenarios. JRC81666, EUR 26008 EN, Petten, Netherlands, available on ehron.jrc.ec.europa.eu.

Roelofs F., Von Estorff U., 2014. Top Down Workforce Demand from Energy Scenarios: Influence of Long Term Operation. JRC92340, EUR 26962 EN, Petten, Netherlands, available on ehron.jrc.ec.europa.eu.

Simonovska V., 2012. Modelling Study – EHRO-N data contribution (Excel file). JRC-IET, Petten, Netherlands.

Simonovska V., Estorff U. von, 2012. Putting into Perspective the Supply of and Demand for Nuclear Experts by 2020 within the EU-27 Nuclear Energy Sector. Report EUR 25291 EN, Petten, Netherlands.

Van Den Durpel L., Yacout A., Wade D.C., Taiwo T., 2008. DANESS v4.0: an integrated nuclear energy system assessment code. PHYSOR 2008, Interlaken, Switzerland.

WNA, 2014. WNA Website. www.world-nuclear.org, accessed February 2014.

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.