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Top-down workforce demand extrapolation from nuclear energy scenarios

Ferry Roelofs
Ulrik von Estorff

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Institute for Energy and Transport

Contact information
Ulrik von Estorff
Address: Joint Research Centre, P.O. Box 2, NL-1755 LG, Petten, The Netherlands
E-mail: ulrik.von-estorff@ec.europa.eu
Tel.: +31 224 56 2325

http://iet.jrc.ec.europa.eu/
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Top-down workforce demand extrapolation from energy scenarios

Ferry Roelofs
Nuclear Research and consultancy Group

Ulrik von Estorff
European Commission, Joint Research Centre,
Institute for Energy and Transport

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Summary

The EHRO-N team provides the EC with essential data related to supply and demand for nuclear experts based on bottom-up information from the nuclear industry. The current report deals with an alternative approach to derive figures for the demand side information of the nuclear workforce. Complementary to the bottom-up approach taken by the EHRO-N team at the Institute for Energy and Transport of the Joint Research Centre, a top-down modeling approach extrapolation of nuclear energy demand scenarios is followed here in addition to the survey information.

In this top-down modeling approach, well accepted nuclear energy demand data is used to derive the number of nuclear power plants that are in operation and under construction as a function of time from 2010 up to 2050 assuming that the current reactor park will be replaced by generic third generation reactors of 1400 MWe or 1000 MWe. Based on workforce models for operation and construction of nuclear power plants, the model allows a prediction of these respective workforces. Using the nuclear skills pyramid, the total workforce employed at a plant is broken down in a nuclear (experts), nuclearized, and nuclear aware workforce. With retirement profiles for nuclear power plants derived from the bottom-up EHRO-N survey, the replacement of the current workforce is taken into account.

Depending on the assumed nuclear energy demand scenario and the type (size) of new build reactors, the analysis shows that about 95 to 160 new reactors are required to fulfil the demand for nuclear energy. The total number of the involved in construction of nuclear power plants equals ~50000 (70000 peak) for the scenario in which 160 reactors are constructed and ~20000 (40000 peak) for the scenario in which 95 reactors are constructed.

The peak of the new workforce (partly replacing the retiring workforce and additionally keeping up with the growing total workforce demand) for nuclear experts is to be expected at the end of the considered period (2050) and amounts to about 7500-10000 nuclear experts. The peak workforce for nuclearized employees is also to be expected around 2050 and amounts to about 50000-65000 nuclearized employees. On the other hand, the peak workforce for nuclear aware employees is to be expected around 2020 and amounts to about 25000-50000 nuclear aware employees. Under the assumption of a typical amount of part-time contracts in the nuclear industry of about 10%, this relates to about 45000-80000 new jobs on the short term (2020) and 70000-100000 jobs on the long term (2050).

When comparing to historical data for the nuclear capacity being installed at the same time in Europe, it is clear that the expected future capacity to be installed at the same time in Europe is significantly lower (factor of 2) than in the early 1980's. However, it should be realized that the skills demand might have been more relaxed in those days. Furthermore, a steep rise in construction is to be expected within 10 to 15 years. This is due to the fact that not only additional nuclear power plants need to be built to keep up with the growing nuclear energy demand, but also to replace the current nuclear reactor park. In order to deal with this steep rise, the nuclear industry may consider buying time by extending the lifetime of the current nuclear reactor park.

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Introduction

EHRO-N or the European Human Resource Observatory for the Nuclear Energy Sector is the initiative of the European Nuclear Energy Forum (ENEF), with the task to build a system for monitoring the supply of and demand for experts needed for the nuclear energy sector in the EU-27 and the enlargement and integration countries for the years to come until 2020. EHRO-N provides the EC with essential data related to supply and demand for nuclear experts in the EU27 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 EU27 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 to two surveys that are sent higher education institutions in EU-27 and the enlargement and integration countries that offer nuclear-related degrees, and to nuclear stakeholders, who are active on the EU-27 and the enlargement and integration countries nuclear energy labour 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). In addition to the bottom-up approach taken by the EHRO-N team, an alternative top-down modeling approach will be undertaken in the current report.

Therefore, the objective of the current analysis is to apply an alternative top-down modeling approach to derive figures for the demand side information of the nuclear workforce.

First in chapter 2 the computational tool which serves as a base for the current analysis is introduced. After that, chapters 3 through 6 describe the input for the analysis. Chapter 3 describes the nuclear energy demand scenarios. Chapter 4 shows the current reactor park and the assumptions taken for new reactors to be constructed. Chapter 5 explains the workforce models used to calculate the workforce for construction and operation of a nuclear power plant. Chapter 6 describes the age profiles as derived from the bottom-up EHRO-N survey and shows how these are used to construct retirement profiles. The case to be analyzed is shortly introduced in chapter 7. Importantly, the results of the analysis for the bounding cases are described and explained in chapter 8. Finally, chapter 9 present the conclusions.

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DANESS Analysis Tool

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.

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.

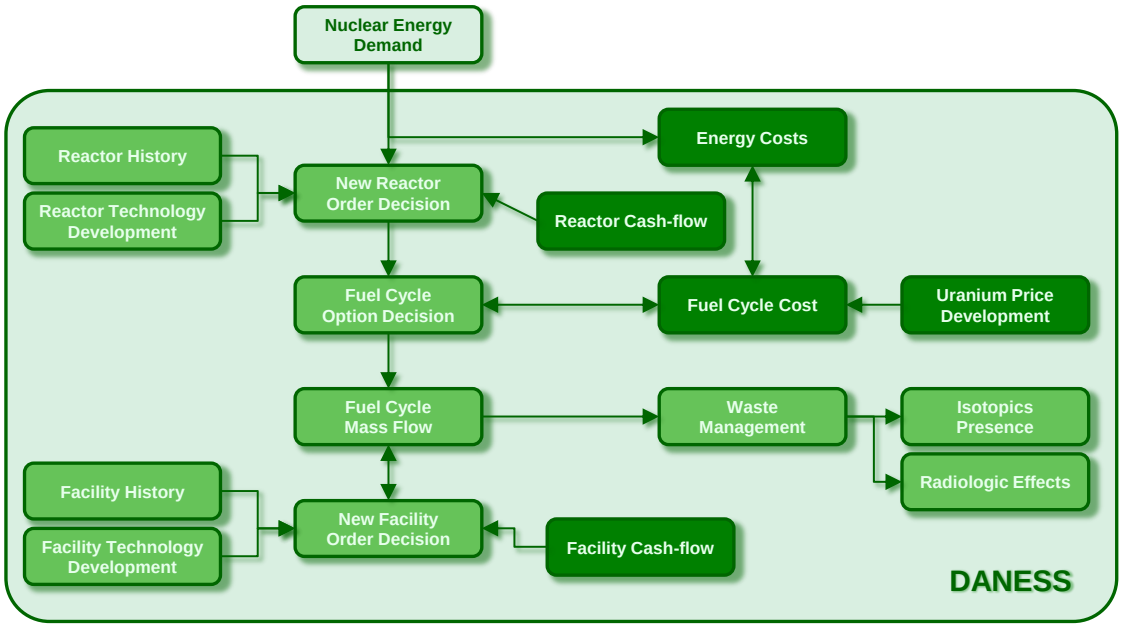

Figure 1: DANESS Fuel Cycle Functionality

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, radiotoxities, and decay heat. Where the results for material flows and nuclide inventories showed a good agreement, the results for radiotoxities and decay heat showed deviations between the results of the different codes.

Nuclear Energy Demand Scenarios

EC Energy Roadmap 2050

In 2011, the European Commission (2011) issued the EC Energy Roadmap 2050. Within this roadmap, different scenarios are analysed for the energy production in the EU27 countries. The reference business as usual scenario depicted in figure 2 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 Delayed CCS scenario leads to the highest penetration of nuclear energy and will therefore be most demanding for the current assessment. Therefore, the Delayed CCS scenario is selected for the current workforce demand extrapolation.

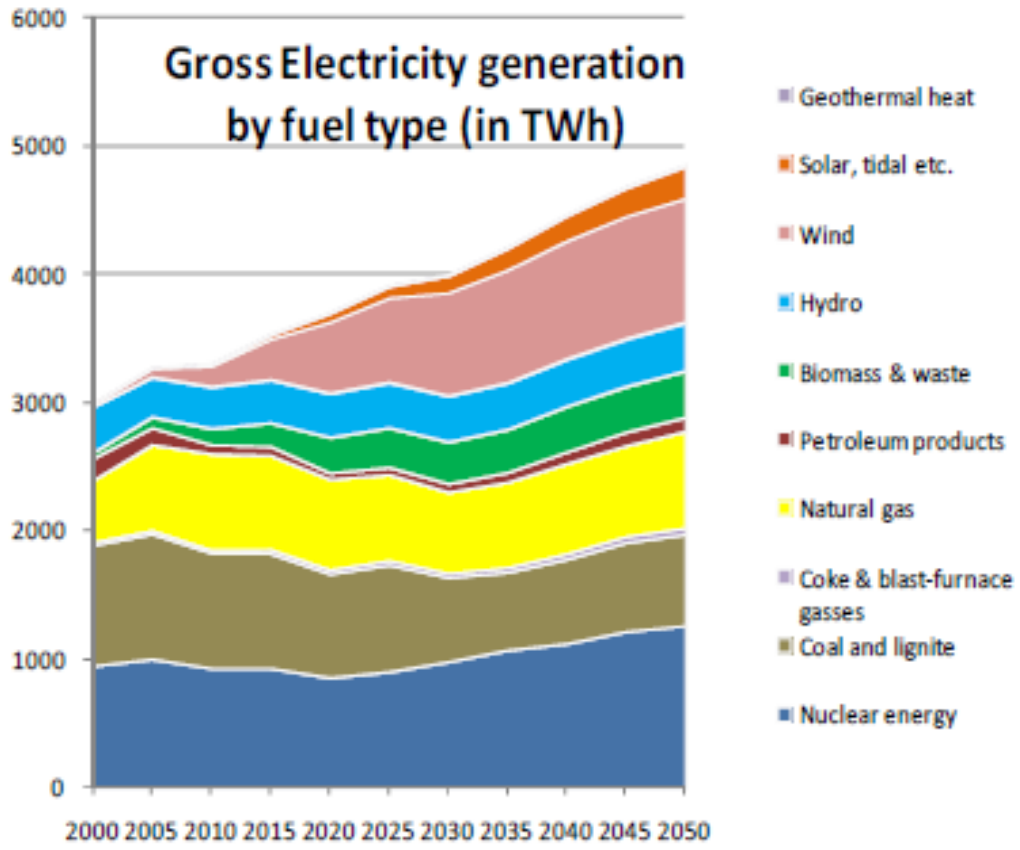

Figure 2: Gross electricity generation by fuel type for the business as usual scenario (European Commission, 2011)

As this nuclear energy demand scenario is derived for the EU27 countries only, extrapolation to EU27 countries including the enlargement and integration countries is required (see figure 3). 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 EU27 with enlargement and integration countries is about 16% higher than the demand for EU27 countries without enlargement and integration countries.

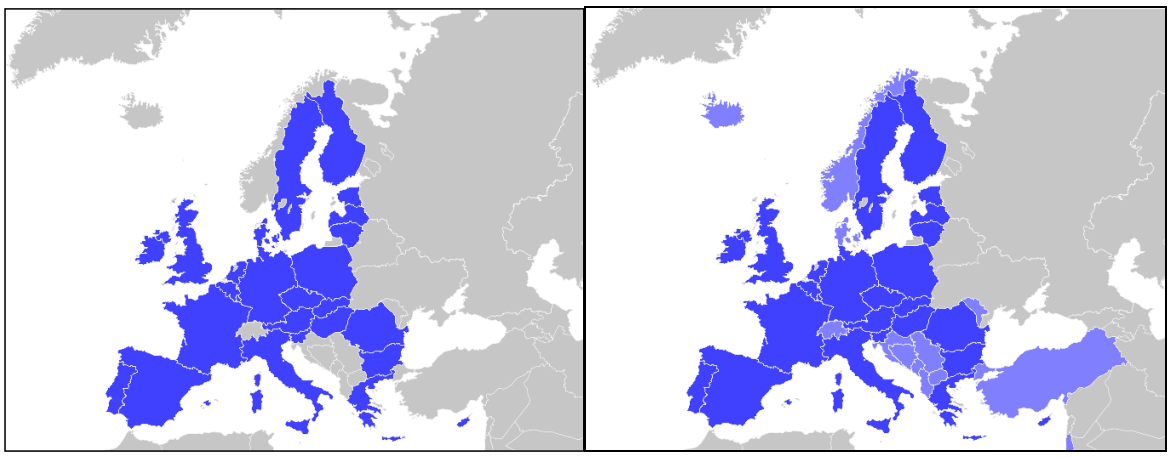

Figure 3: EU27 (left) and EU27 with enlargement and integration countries (right).

Figure 4 shows the resulting nuclear energy demand for the period 2000-2050. As the current analyses start in 2010, the period 2000-2010 is omitted for the actual calculations.

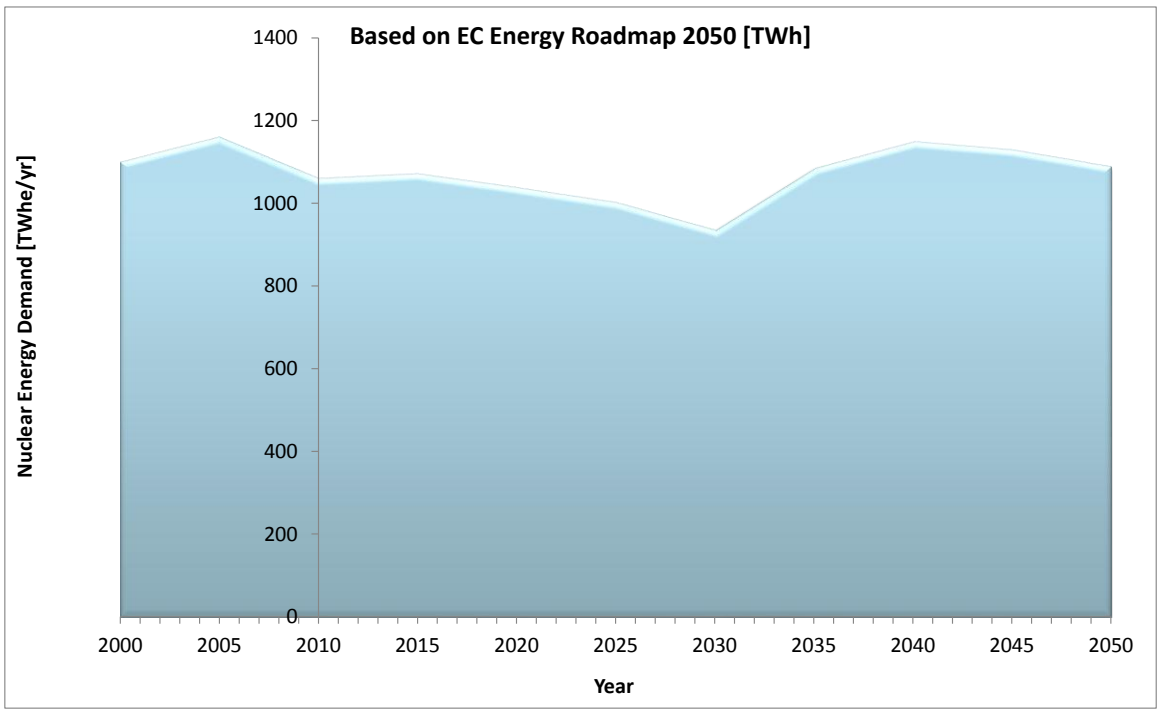

Figure 4: Nuclear Energy Demand based on the EC Energy Roadmap 2050 for EU27 countries including enlargement and integration countries.

OECD/IEA Technology Roadmap

In 2010, the OECD/IEA (2010) issued the OECD/IEA Technology Roadmap Nuclear Energy. This roadmap is based on the so-called BLUE map scenario from the IEA Energy Technology Perspectives report (IEA/OECD, 2010). The energy production in the OECD countries derived from this BLUE map scenario is depicted in figure 5 and used for the current workforce demand extrapolation.

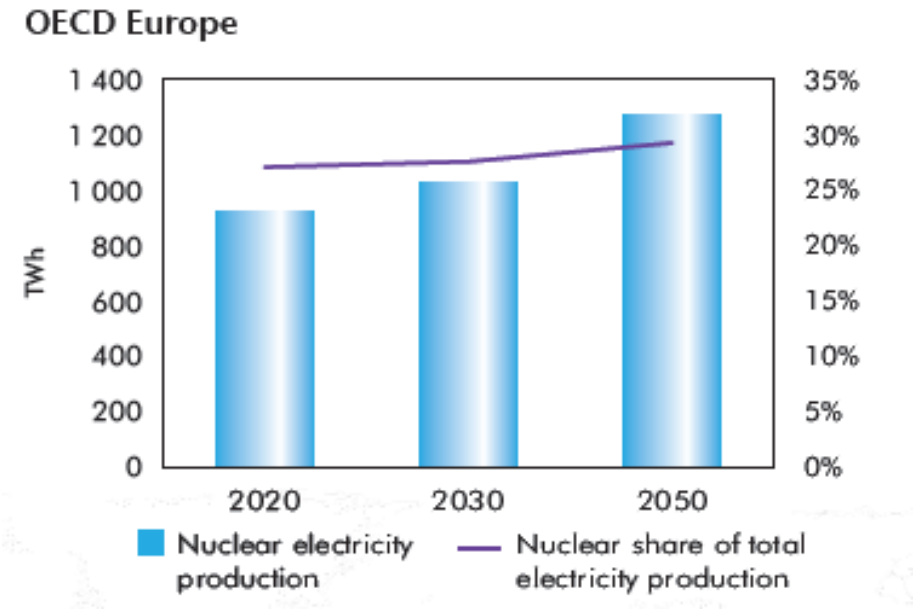

Figure 5: Gross nuclear electricity generation in OECD Europe (OECD/IEA, 2010)

As this nuclear energy demand scenario is derived for the OECD Europe countries only, extrapolation to EU27 countries including the enlargement and integration countries is required (see figure 6). 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 EU27 with enlargement and integration countries is about 7% higher than the demand for the OECD Europe countries.

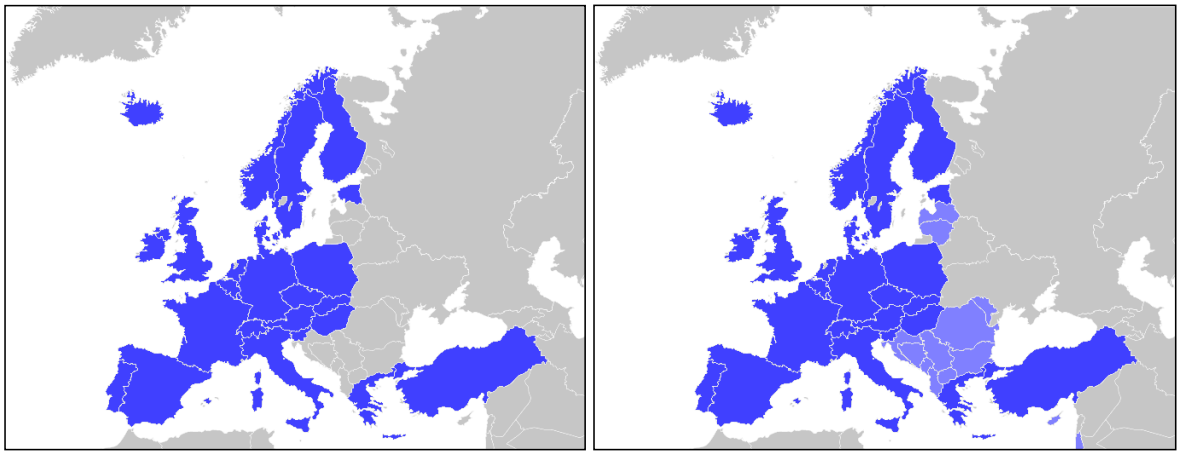

Figure 6: OECD Europe (left) and EU27 with integration and enlargement countries (right).

Figure 7 shows the resulting nuclear energy demand for the period 2010-2050.

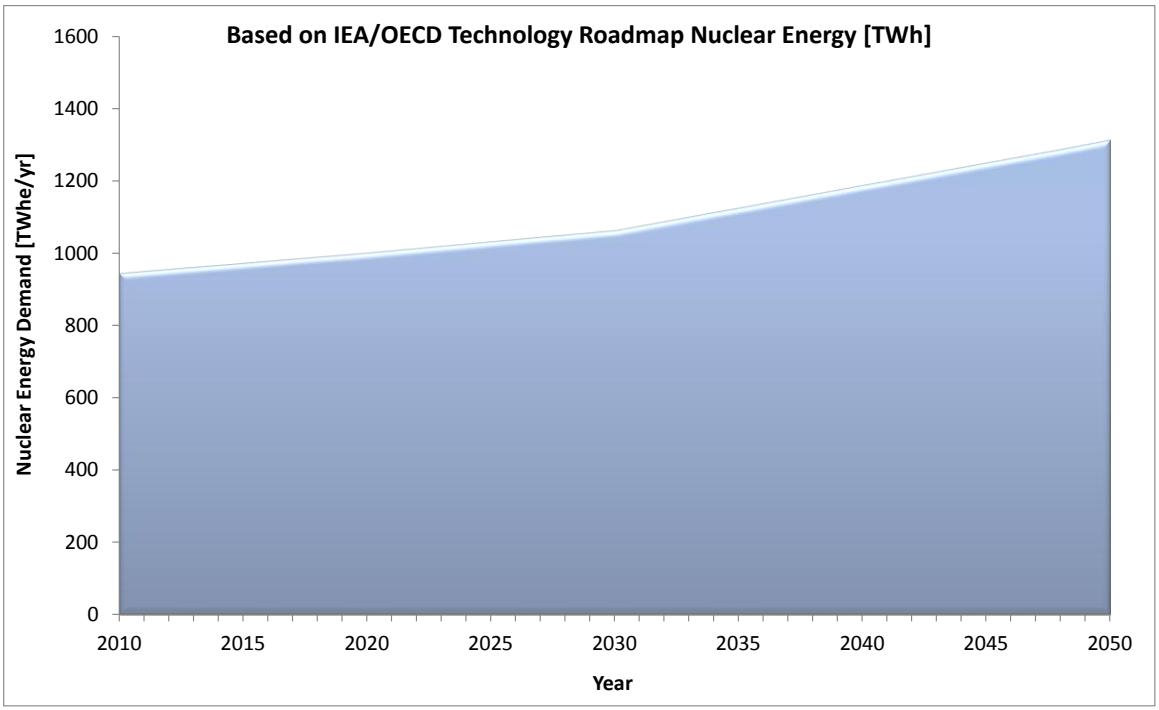

Figure 7: Nuclear Energy Demand based on the OECD/IEA Technology Roadmap for EU27 countries including enlargement and integration countries.

Nuclear Energy Demand Scenarios in Comparison

Figure 8 shows the two considered nuclear energy demand scenarios in comparison. During the period 2010-2050, both nuclear energy demand scenarios predict a net growth of nuclear energy demand from about 1000 TWhe/yr to about 1400 TWhe/yr. Within the EC Energy Roadmap 2050 based scenario, the initial demand of about 1100 TWhe/yr first slowly decreases, but after 2020 shows an increase to about 1150 TWhe/yr in 2040 and after that a decrease to about 1100 TWhe/yr in 2050. The OECD/IEA Technology Roadmap based scenario shows a steady increase from about 900 TWhe/yr in 2010 to about 1300 TWhe/yr in 2050. It is clear that although the two scenarios are different when details are considered, they actually in the end show more or less a nuclear energy demand at about the same order of magnitude. Especially when one takes into account that almost the complete energy demand has to be fulfilled with new nuclear reactors as can be derived from the reactor park shutdown profile shown in the next chapter.

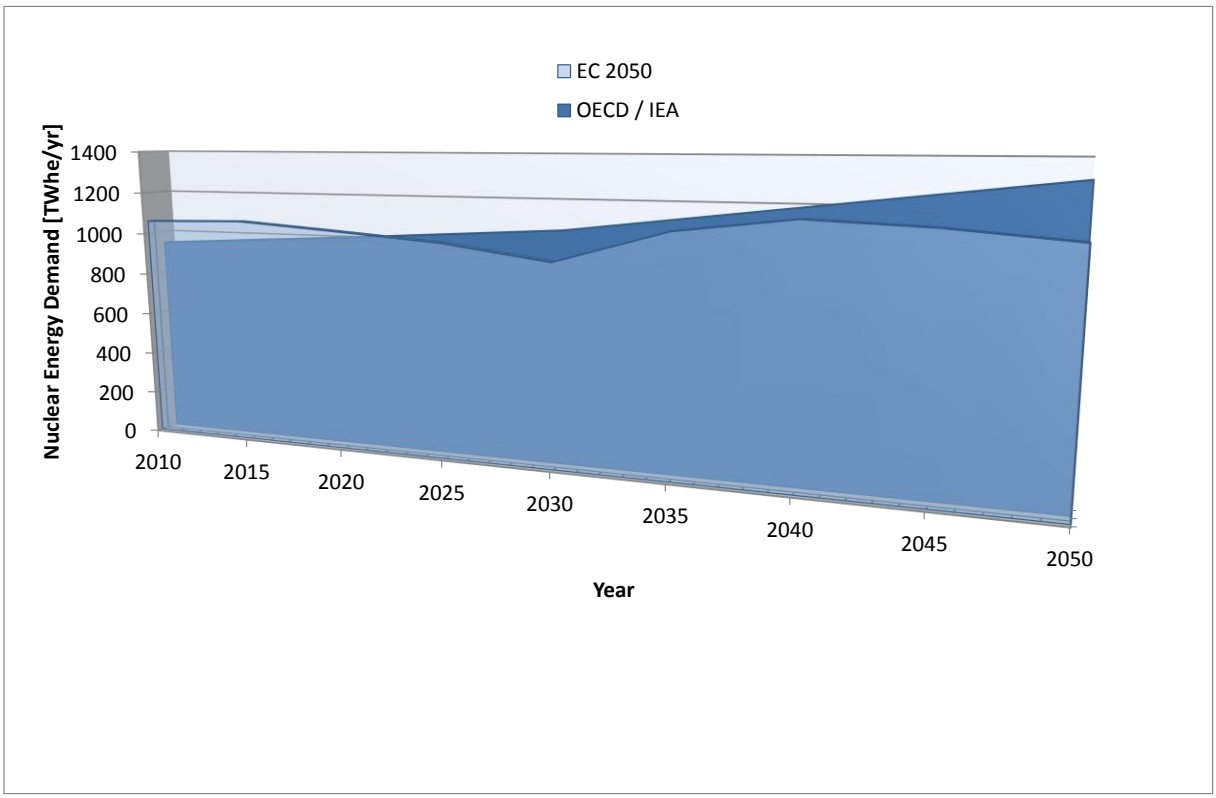

Figure 8: The EC Energy Roadmap 2050 and the OECD/IEA Technology Roadmap based nuclear energy demand scenarios.

Reactor Park

Current Reactor Park

The current reactor park is modelled based on data retrieved from WNA (2013). 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 again from data provided by WNA (2013). 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. 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 9.

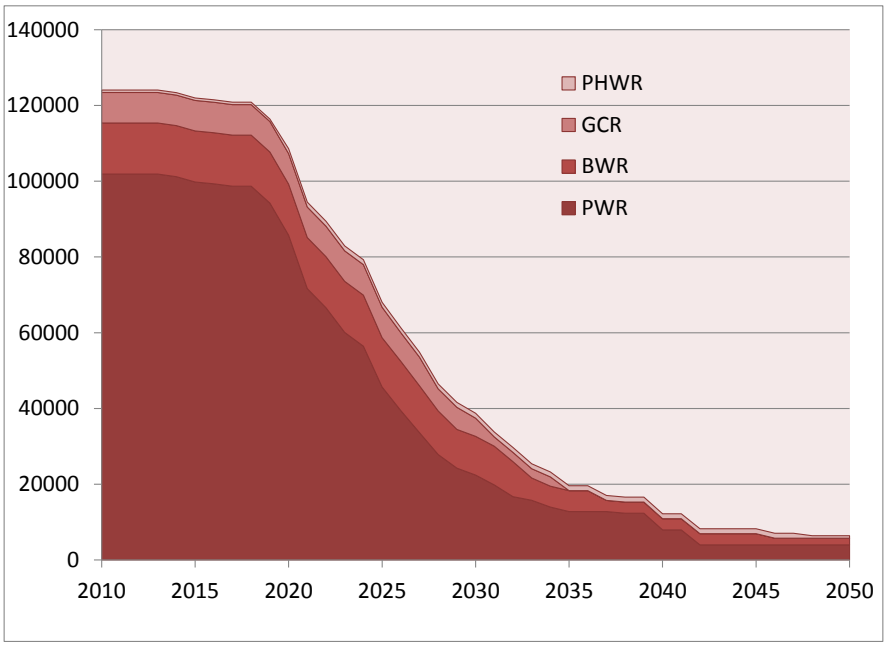

Figure 9: Shutdown profile of the current reactor park.

New Reactors

As specified by EHRO-N (2012) two different generic third generation nuclear reactors are assumed to be constructed in order to fulfil the energy demand. These reactors only differ in net electric output. The first generic reactor to be assumed produces 1400 MWe, whereas alternatively, the second generic reactor assumed produces 1000 MWe. The two nuclear energy demand scenarios described in chapter 3 are simulated assuming construction of only one of these types of generic reactors. In both cases, an efficiency of 36%, a load factor of 80%, and a lifetime of 60 years are assumed. Table 1 summarizes the main characteristics of these two generic nuclear reactors.

Table 1: Main characteristics of two assumed generic third generation reactors

Reactor	**Power [MWe]**	**Efficiency [%]**	**Load Factor [%]**	**Lifetime [yr]**
Gen III LWR: A	1400	36	80	60
Gen III LWR: B	1000	36	80	60

Workforce Model

Operations

One of the purposes of the current analysis is to determine an estimate for the workforce required for operation of the nuclear plants. Most data in literature are based on a typical nuclear plant of about 1000 MWe, e.g. Johnson (1982), NIA (2006), IAEA (2007), Tuohy (2009), Mazour et al. (2010). For such plants, the estimates vary from 300 to 500 workers. This is significantly lower than the results for the current Gen-II reactor park of a yearly US survey by Goodnight (2009) which shows an average staff of 600 to 800 workers for a 1000 MWe plant. However, it is expected that future reactors can be operated more efficiently. The reactors under consideration in this article (for existing reactors an average size is assumed for reactor type) have a capacity varying from about 500 MWe to 1400 MWe.

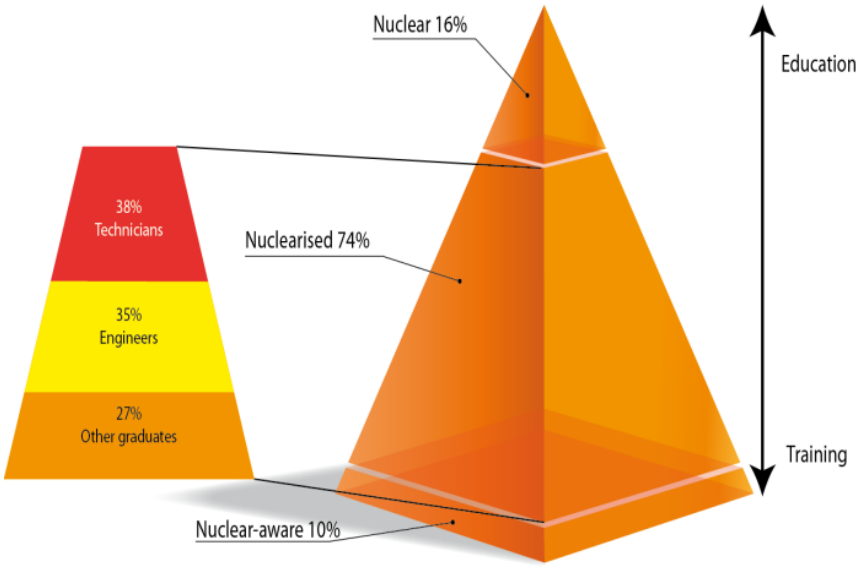

Figure 10: Nuclear Skills Pyramid (Simonovska & Von Estorff, 2012)

Kenley et al. (2004) propose an approximately linear relationship between capacity and direct employment, assuming that no scale effects would occur. For the current assessment however, scale effects are taken into account, assuming that with increasing power, the growth in workforce would gradually decrease. In such cases, this would lead to large differences between small sized reactors (200 MWe) and medium sized reactors (600-1000 MWe). Whereas, the differences between medium sized reactors and large sized reactors (up to 2000 MWe) are not that large (assuming indeed that the workforce becomes more or less independent from the reactor capacity). To this purpose, an equation has been developed which reads $w = max[a \bullet ln(P+b)+c;\ 100]$, in which w represents the workforce in fte (full time equivalent), P represents the electric power in MWe and a, b, and c are model constants equal to 400, 400, and -2450 respectively. This equation is applied for nuclear power plants smaller than 2000 MWe. The workforce derived from this model is subdivided with respect to the data from the nuclear skills pyramid as presented by Simonovska & Von Estorff (2012) in figure 10. Figure 11 shows the outcome of the above described equation. Indeed for a plant of 1000 MWe, this graph shows that the above mentioned model predicts a workforce in the range of 300 to 500 fte.

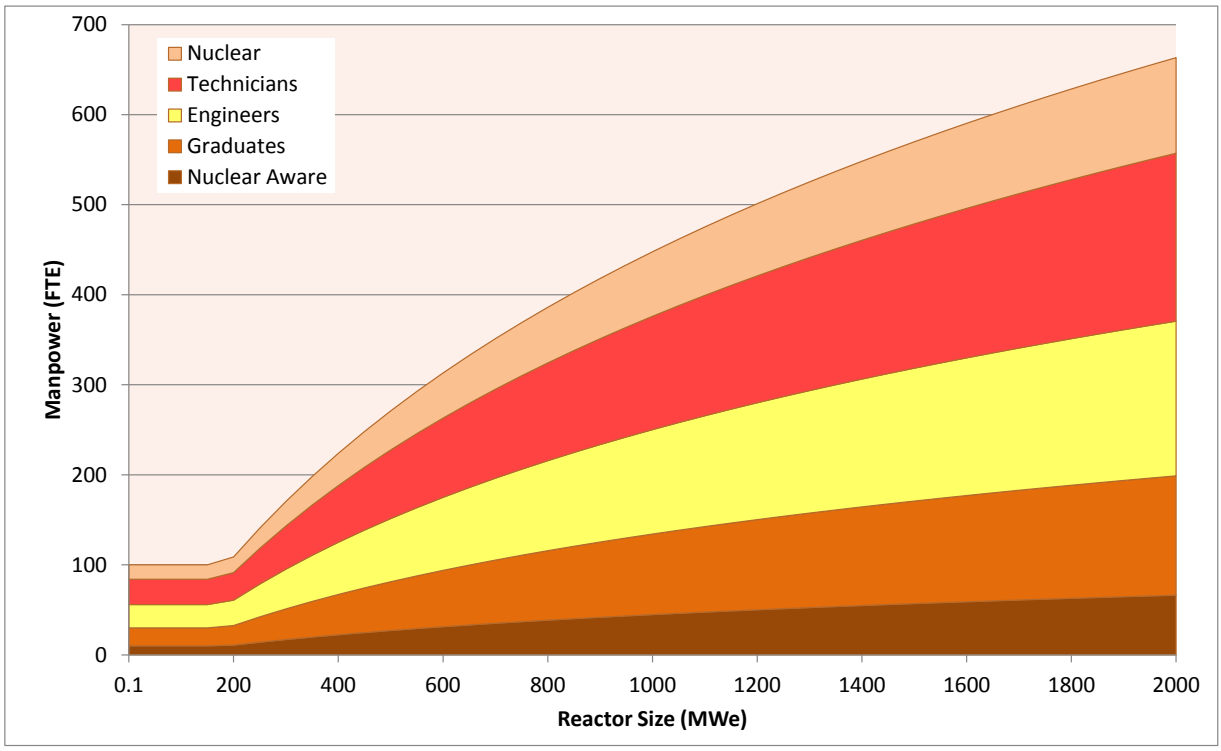

Figure 11: Graphical representation of the manpower required for different sizes of nuclear reactors based on the model described by Roelofs et al. (2011)

Construction

In order to evaluate the manpower requirements for the construction of a future fleet of nuclear reactors in Europe, manpower requirements are largely based Mazour (2007), which is basically in line with the estimates provided by NIA (2006) and Orkilow et al. (2008). The literature data is interpreted and from this data, profiles have been derived for the construction of nuclear reactors, taking into account a foreseen construction time of the reactors of about 6 years. It should be noted that the largest part of this construction workforce will require no specific nuclear skills, see e.g. DOE (2005). Although it is recognized generally, that workers with experience in nuclear projects provide better quality services. For the scenarios, the time evolution of the determined construction manpower requirements will be presented as a 10 year walking average.

Figure 12 shows the manpower requirements for the construction of one nuclear power plant based on data provided by Mazour (2007). Within his data, Mazour (2007) distinguishes between high grade professionals, professionals, technicians, and craftsmen. These categories have been translated to the nomenclature used in the nuclear skills pyramid, i.e. it is assumed that high grade professionals correspond with nuclear educated employees, professionals correspond with nuclearized engineers, technicians correspond to nuclearized technicians, and craftsmen correspond to the nuclear aware workforce.

Deffrennes & Gress (2012) in their study for DG-Energy assume 2700 people working for construction of a nuclear power plant during 7 years. Assuming a part-time rate of 5% (Brinkman et al., 2013) this leads to about 2500 fte during 7 years. In comparison with the data shown in figure 12 based on IAEA data from Mazour (2007), it can be noted that this 2500 fte corresponds well to the peak value.

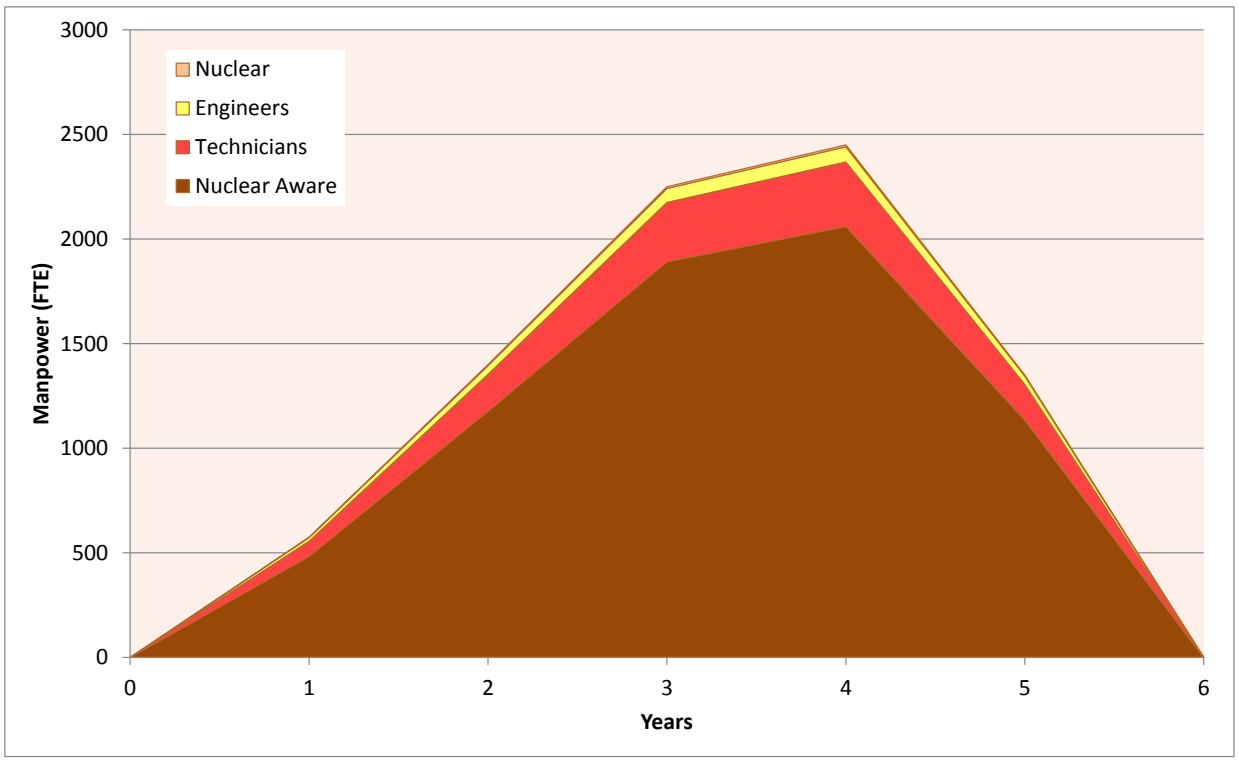

Figure 12: Graphical representation of the manpower required for construction of a nuclear power plant based on data from Mazour (2007)

Retirement Profile

Simonovska & Von Estorff (2012) provide an age distribution of employed engineers in European countries. In a follow up of this study, Simonovska (2012) has derived the age distribution for nuclear experts. This distribution is represented in figure 13.

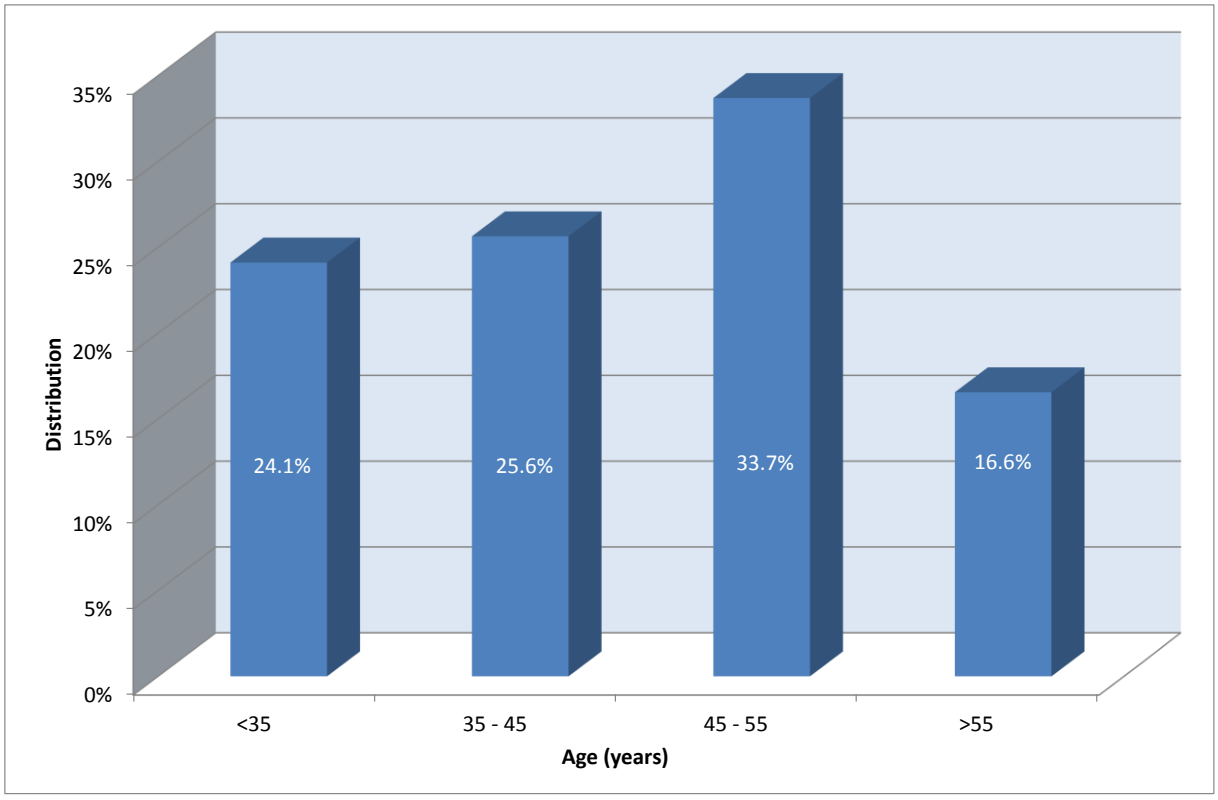

Figure 13: Age profile of nuclear experts according to Simonovska (2012)

For the current analysis, the following assumptions have been made in order to derive the retirement profile of the nuclear workforce which is shown in figure 14:

- The EHRO-N data represented in figure 13 on a five yearly basis has been interpolated to a yearly profile,
- The retirement profile based on EHRO-N data for the nuclear experts is also used for the nuclearized and nuclear aware workforce as no detailed data is available for these categories,
- An average retirement age of 65 is assumed,
- A third order polynomial fit is constructed through the EHRO-N data for further use.

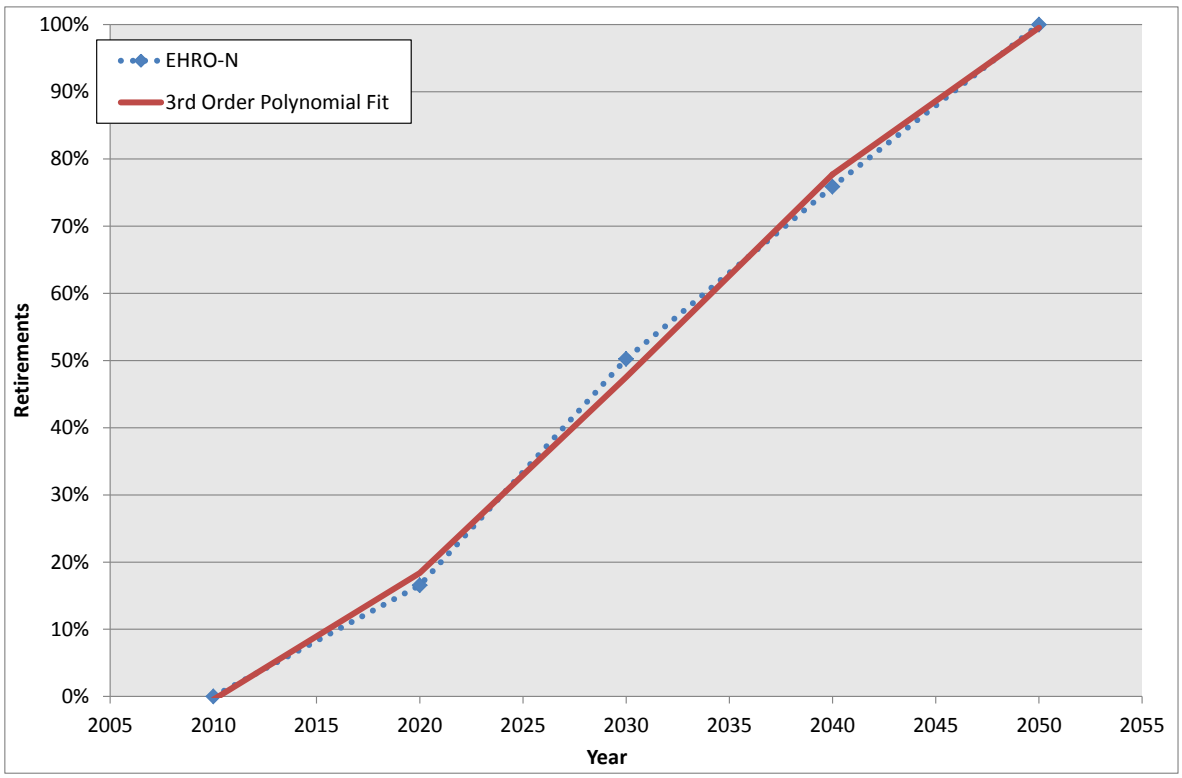

Figure 14: Retirement profile

Cases

A total number of four cases have been analyzed for the current purposes varying two parameters. The first parameter which is varied is the nuclear energy demand scenario. The two scenarios described in chapter 3 are considered for this purpose. The second parameter which is varied is the size of the reactors to be constructed to replace the current reactor park on the one hand and to keep up with the nuclear energy demand on the other hand. These reactors have been described in chapter 4. Table 2 summarizes the analyzed cases.

In the following chapter only results of two cases will be presented. The selected cases are the cases which bound the range of results. The first case to be presented therefore is case 1A. This case for the EC Energy Roadmap 2050 shows the lowest demand curve for nuclear energy and apart from is based on construction of relatively large reactors which require less workforce than the smaller reactors. Therefore, case 1A will set the lower boundary of the range of results. Case 2B on the other hand sets the higher boundary of the range of results. This case shows the highest demand curve for nuclear energy and is based on construction of relatively small reactors which require more workforce than the larger reactors.

Table 2: Analyzed cases

Reactor Size	**EC Energy Roadmap 2050**	**OECD/IEA Technology Roadmap**
1400 MWe	1A	2A
1000 MWe	1B	2B

Results

Reactor Park Development

The reactor park development is determined by the DANESS code. First of all, this requires an assessment of the energy generation shortage (ΔE). ΔE is determined by a prediction of the energy demand with an assumed planning horizon and the installed reactor capacity. In the determination of ΔE, also the reactors which will be taken out of operation are considered as well as the reactors which are already under construction. Furthermore, also the fuel availability has to be assessed for each reactor type and associated fuel cycle. However, for the purpose of the current analyses it is assumed that there are sufficient natural resources. Therefore, shortage of fuel for one or more types of nuclear reactors will not occur. Finally, small changes in ΔE may be covered by the flexibility in load factors of the different reactors. Basically, small variations in the load factor are allowed, e.g. reflecting the possibility of a utility to decide to have a longer maintenance stop when the energy demand is low enough.

If ΔE is large enough, reactors are constructed based on availability. However, it should be noted that if ΔE is small, DANESS allows shifting a small energy demand to a previous or following year. This will increase the ΔE for such years and therefore, the decision to construct a reactor might shift.

Figures 15 and 16 show the reactor park evolution during the period 2010-2050 for the two considered nuclear energy demand scenarios. Obviously, both scenarios show a replacement of the current reactor park by third generation light water reactors. On top of that, the growing nuclear energy demand is fulfilled by construction of new reactors. The EC Energy Roadmap 2050 scenario requires construction of ~95 – 130 reactors depending on the size of the reactors. On the other hand, the OECD/IEA Technology Roadmap scenario demands the construction of ~115 – 160 reactors.

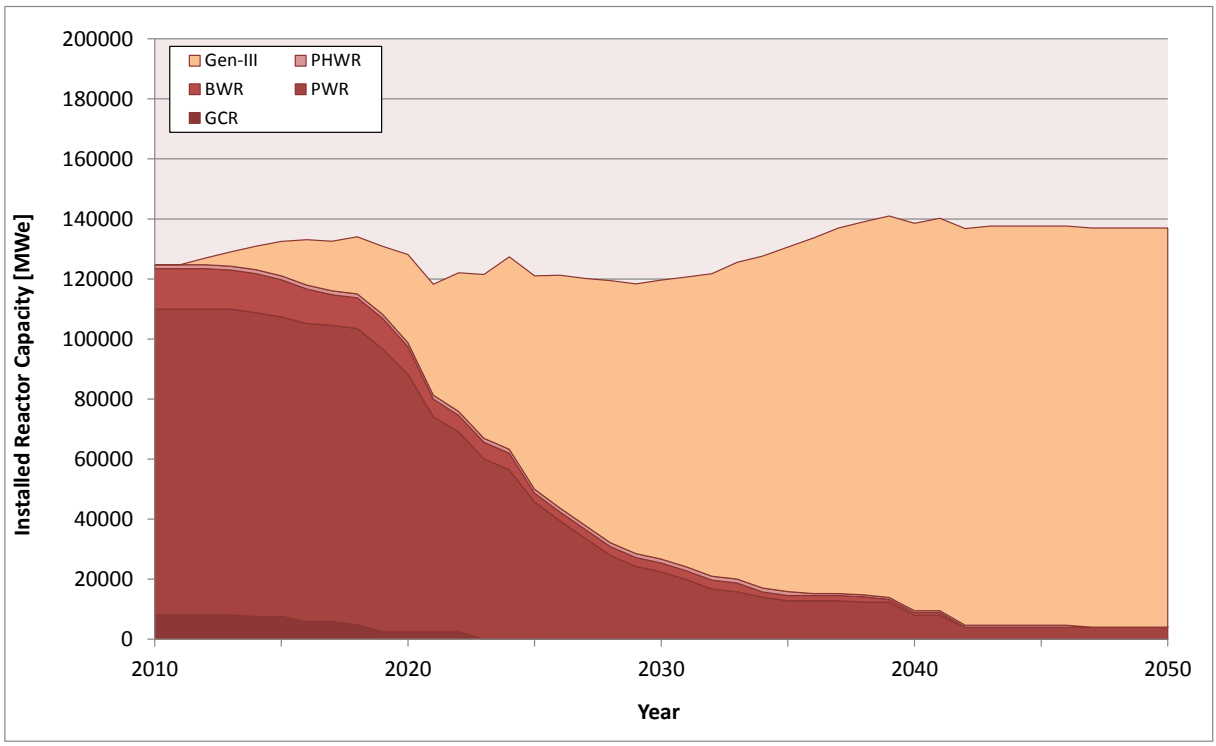

Figure 15: Reactor park development for EC Energy Roadmap 2050 (Case 1)

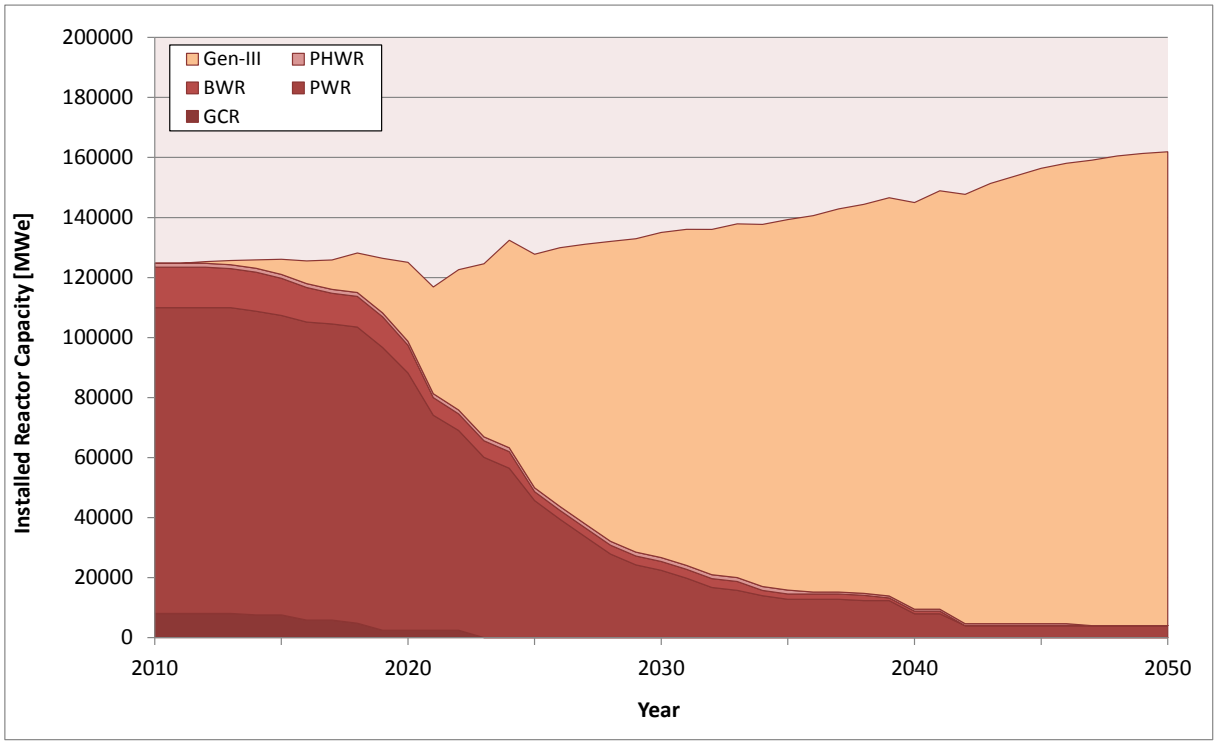

Figure 16: Reactor park development for OECD/IEA Technology Roadmap (Case 2)

Manpower Operations & Construction

Applying the workforce models for operations and construction described in chapter 5, the workforce demand can now be determined top-down from the nuclear energy scenarios considered in chapter 3. Figure 17 and 18 show the workforce demand for operational manpower for the EC Energy Roadmap 2050 and the OECD/IEA Technology Roadmap respectively. Using the nomenclature from the nuclear skills pyramid (figure 10), the data in these figures is visualized for the nuclear, nuclearized (technicians, engineers, graduates), and nuclear aware workforce. As expected the main distinction between the two cases can be ascribed to the nuclear energy demand scenario in combination with the selected reactor size for construction, i.e. 1000 MWe vs. 1400 MWe.

The DANESS model determines when new reactors start operation. Based on that information, the timeframe of construction of these plants can be derived. Using the model described in section 5.2 for the workforce involved in construction of nuclear power plants, the workforce demand for construction of nuclear power plants is given in figures 19 and 20. In this case, again the main distinction between the two cases can be ascribed to the nuclear energy demand scenario in combination with the selected reactor size for construction, i.e. 1000 MWe vs. 1400 MWe.

Using the assumptions to estimate the direct workforce involved in construction of Deffrennes & Gress (2012) in their study for DG-Energy, a rough number of about 70000 fte is calculated to be involved in construction of 100 new power plants during a period of 20 years. In the current analysis, using the IAEA data from Mazour (2007), this corresponds well to the peak value for the scenario in which 160 reactors are constructed.

Finally, figures 21 and 22 show the total workforce demand for operations and construction of nuclear power plants for the two considered scenarios. These figures clearly show a peak in workforce demand around 2020. This peak is mainly related to the construction of new nuclear reactors replacing the current nuclear park and in addition fulfilling the increasing nuclear energy demand.

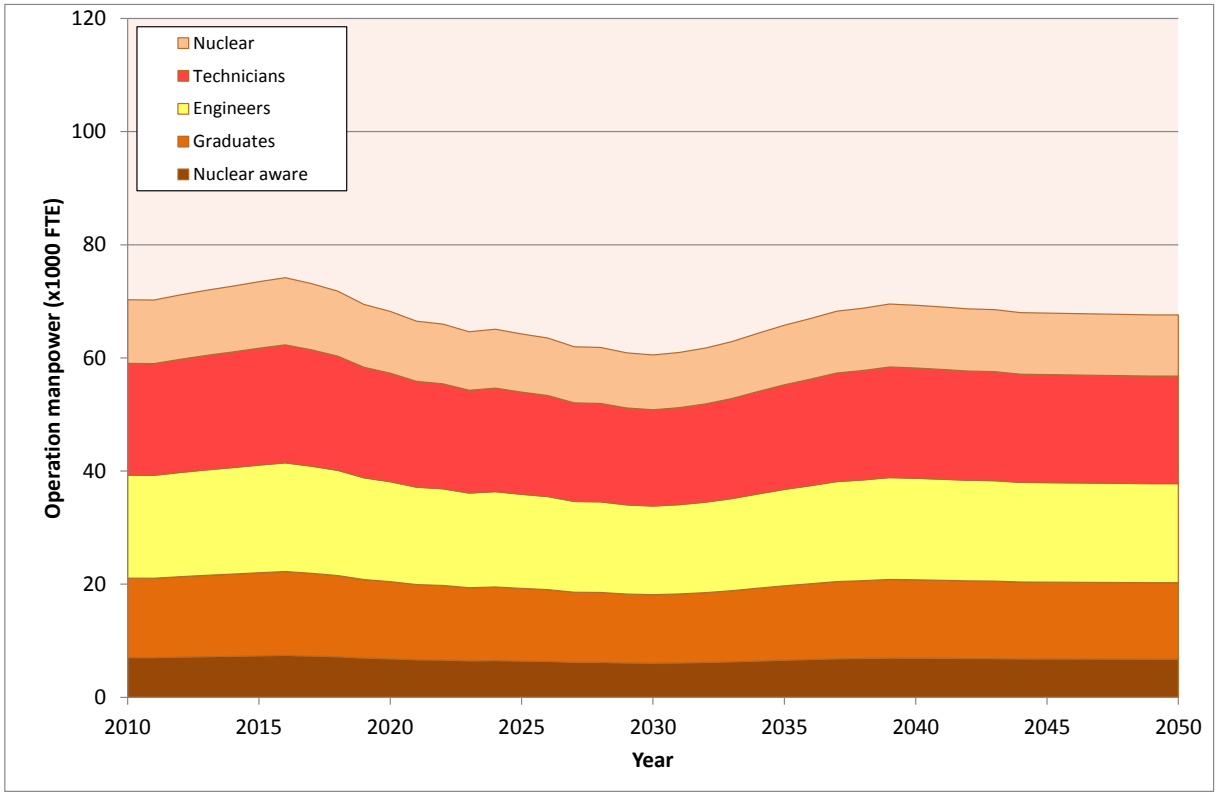

Figure 17: Operational manpower requirements for EC Energy Roadmap 2050 (Case 1A)

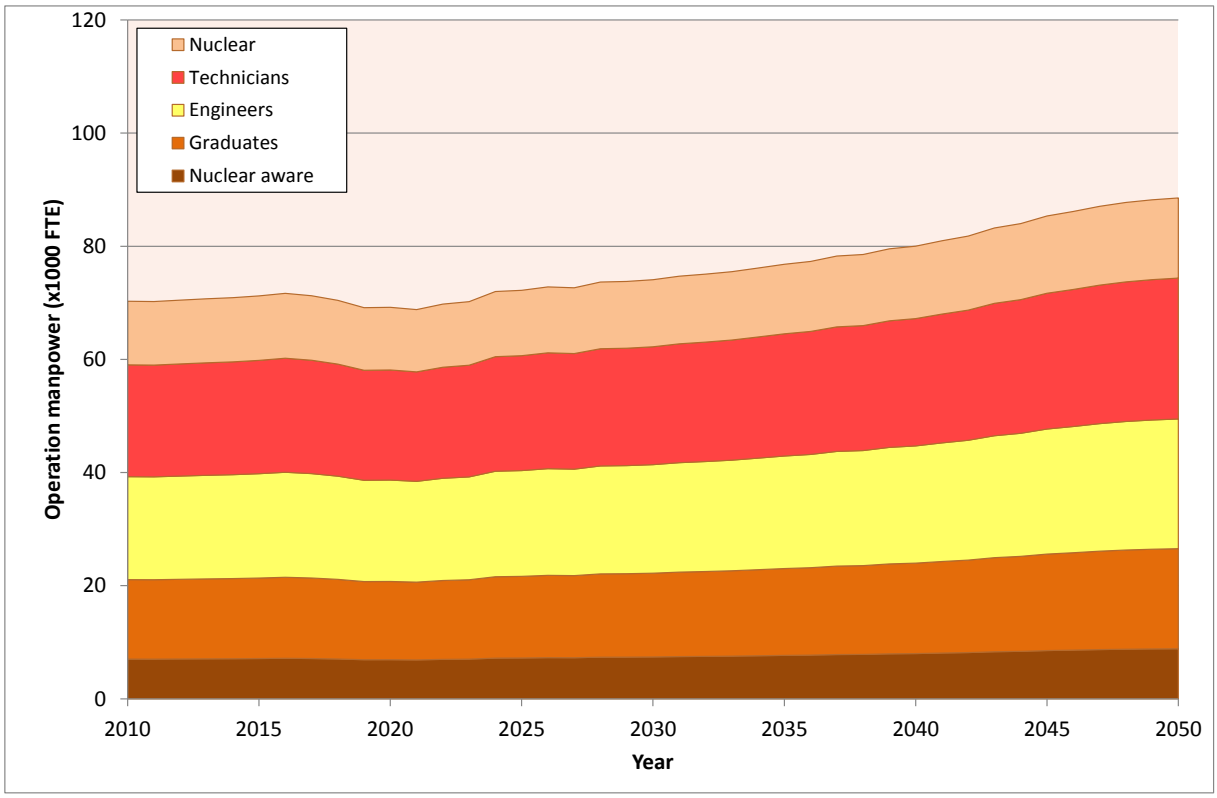

Figure 18: Operational manpower requirements for OECD/IEA Technology Roadmap (Case 2B)

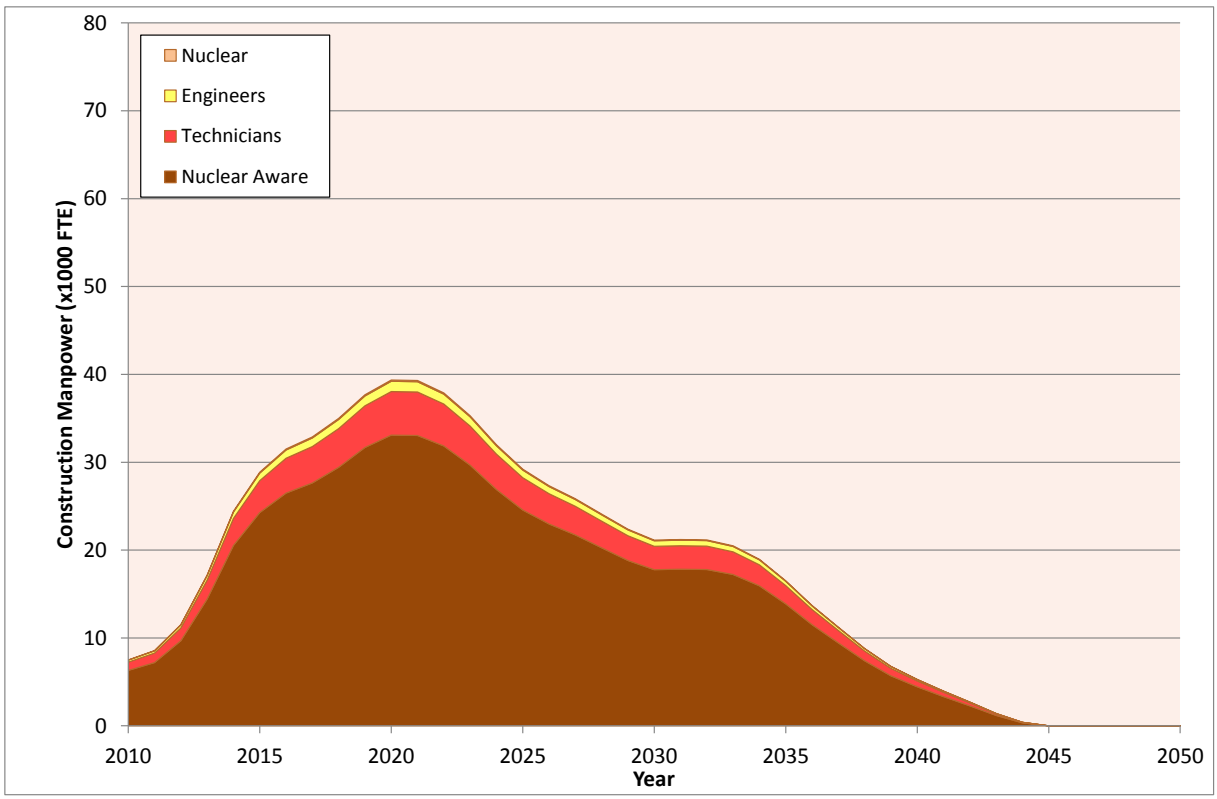

Figure 19: Construction manpower requirements for EC Energy Roadmap 2050 (Case 1A)

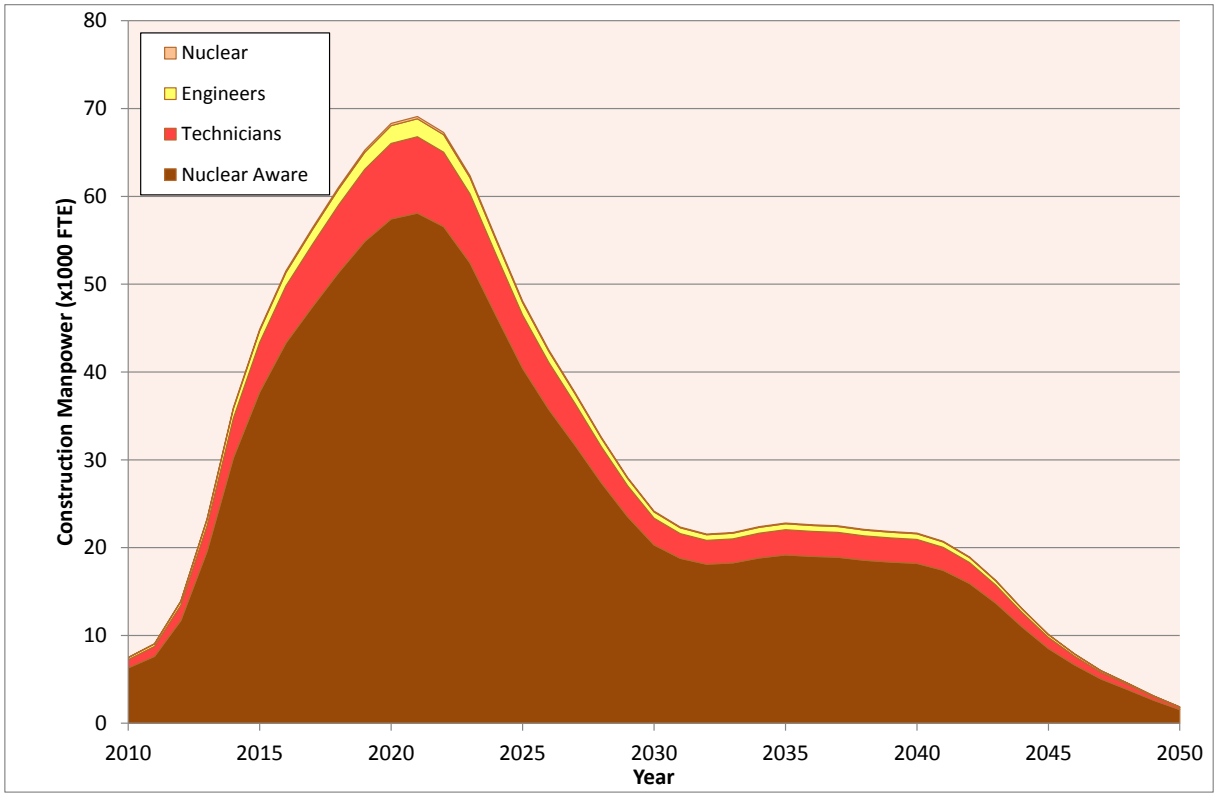

Figure 20: Construction manpower requirements for OECD/IEA Technology Roadmap (Case 2B)

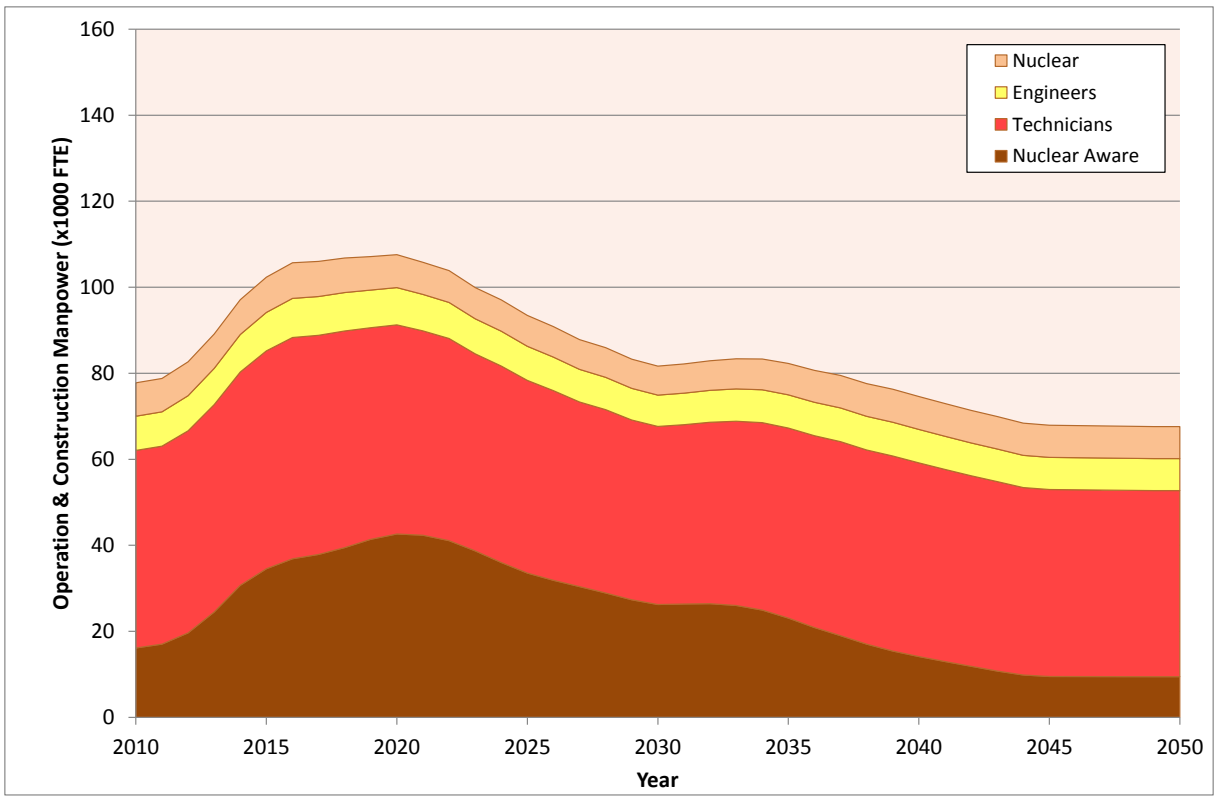

Figure 21: Manpower operations and construction for EC Energy Roadmap 2050 (Case 1A)

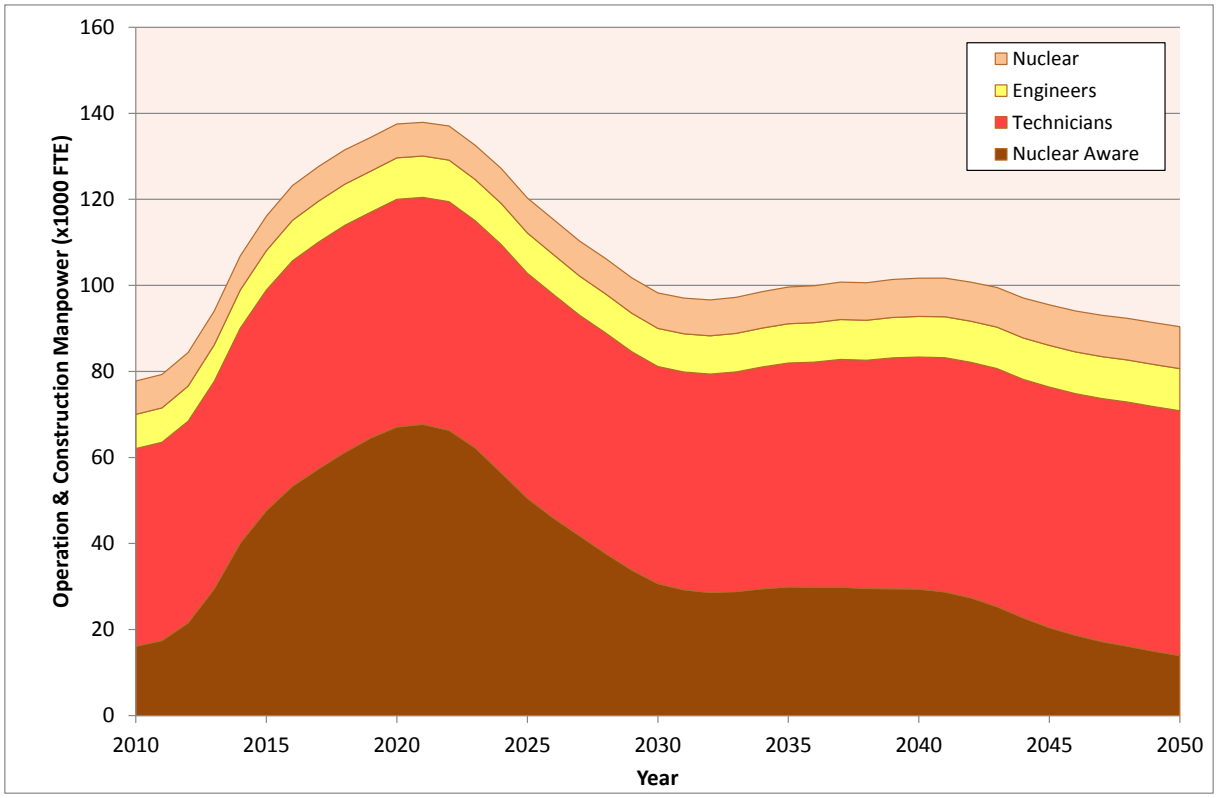

Figure 22: Manpower operations and construction for OECD/IEA Technology Roadmap (Case 2B)

Retirement and Replacement

Using the retirement profiles which have been derived in chapter 6, the workforce demand for construction and operation of nuclear reactors shown in figures 21 and 22 can be visualized in a different way. Figures 23 and 24 show the same data as presented in figures 21 and 22. However, the dashed areas now indicate the retiring workforce, whereas the filled areas represent the new workforce.

When only the filled areas are considered, figures 25 and 26 show the new workforce demand, i.e. the new workforce which partly has to replace the retiring workforce and which additionally has to keep up with the growing total workforce demand. From these figures, the peak workforce demand for nuclear, nuclearized, and nuclear aware can be determined. Table 3 provides an overview of these workforce demands.

The peak demand for the nuclear aware workforce can be expected around 2020. As this workforce is mainly employed in the construction of new plants this coincides with the peak in nuclear power plant construction. The peak demand for the nuclear and nuclearized workforce is found in 2050. This relates to the growing nuclear energy demand predictions in both considered scenarios. The nuclear and nuclearized workforce is mainly employed in the operation of nuclear power plants.

Table 3: Workforce demand for different categories defined in the nuclear skills pyramid.

Category	Workforce Range	Peak Year
Nuclear	7500 – 10000	2050
Nuclearized	50000 – 65000	2050
Nuclear Aware	25000 – 50000	~2020

Under the assumption of a typical amount of part-time contracts (Brinkman et al., 2013) in the nuclear industry of about 5%, this relates to about 42500 to 80000 new jobs on the short term in 2020 and 67500 to 95000 jobs on the long term in 2050.

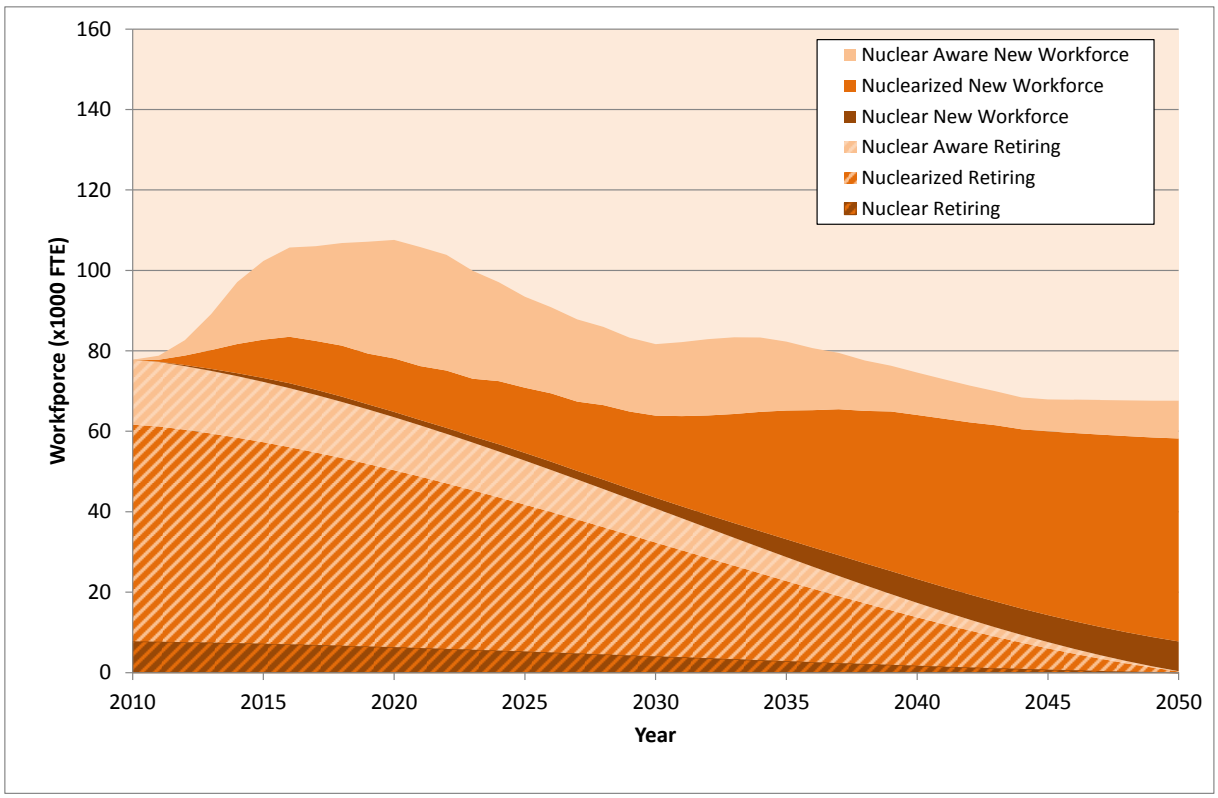

Figure 23: Retirement operations and construction for EC Energy Roadmap 2050 (1B)

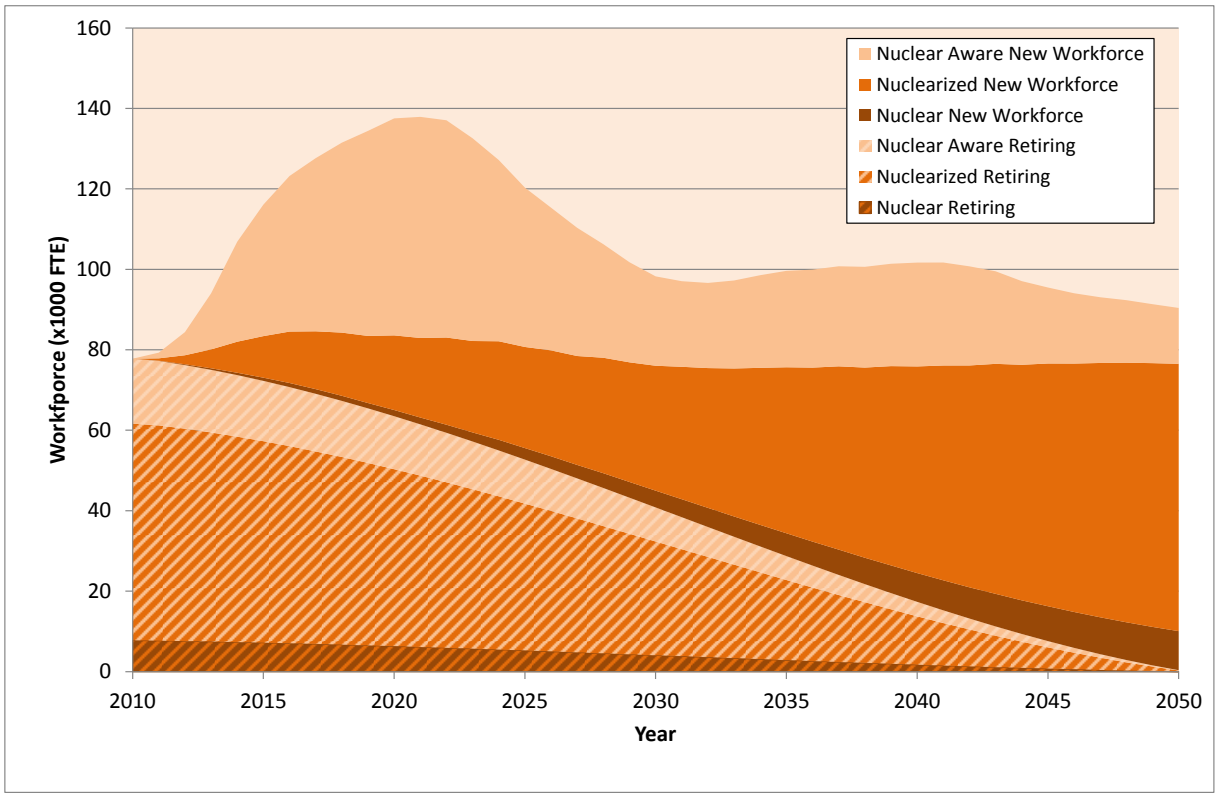

Figure 24: Retirement operations and construction for OECD/IEA Technology Roadmap (2A)

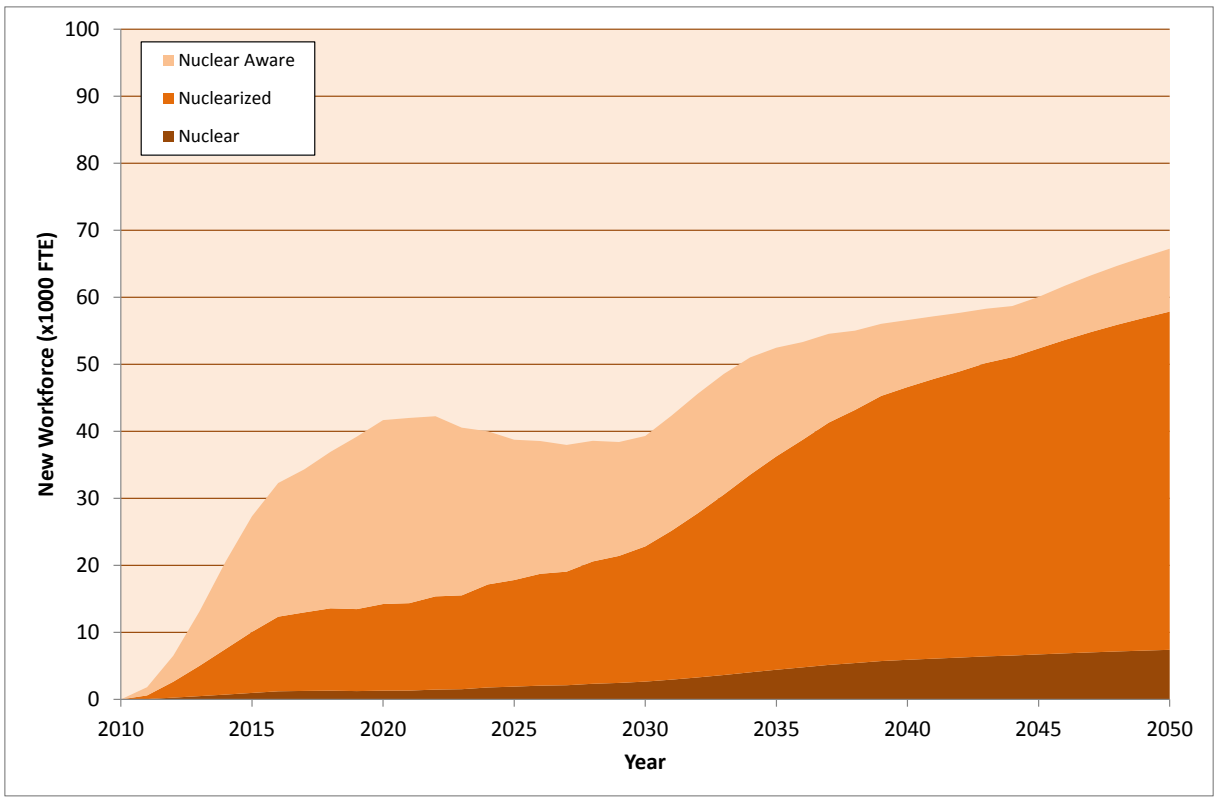

Figure 25: New workforce operations and construction for EC Energy Roadmap 2050 (1B)

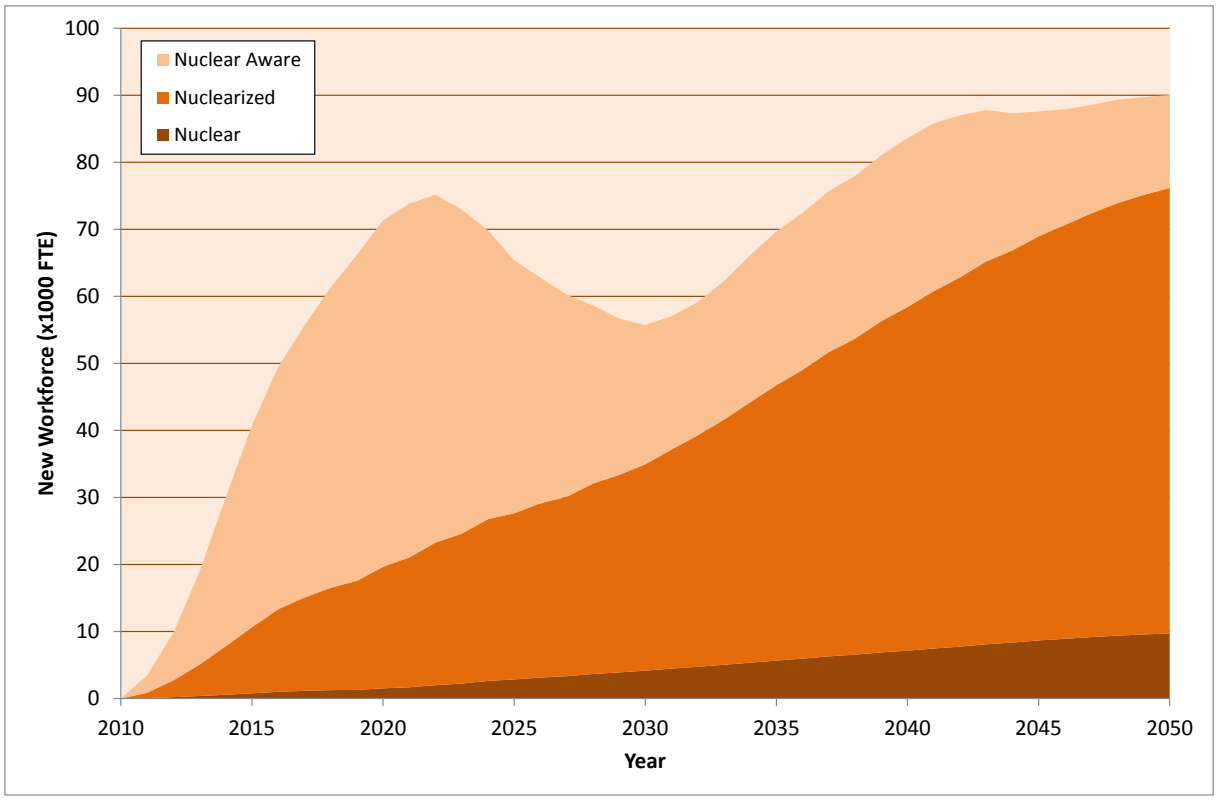

Figure 26: New workforce operations and construction for OECD/IEA Technology Roadmap (2A)

Comparison with Historical Data

In order to put the numbers determined in the current study into perspective, a comparison is made with historical data for the nuclear capacity being installed at the same time. Obviously, a comparison with historical supply chain and nuclear workforce data would provide a better picture, but such data are hard to retrieve and it was decided to exclude this from the current analysis. Figure 27 is taken from Hillrichs (2009) who indicates that this data was retrieved from the IAEA in 2008. When the data for nuclear capacity being installed at the same time provided in this figure for East and West Europe are collected for the years 1951 – 2007, these data can be compared to the data computed by the DANESS model.

Figures 28 and 29 show that when these data are compared, the historical peak values are much larger than the values computed for the coming 40 years. The historical peak value is about twice as high as the expected future peak values. However, these figures also reveal that the future peak values are to be expected within 10 to 20 years and moreover the gradients to reach the peak values appear to be steeper than the historical values. This means that during a relatively short time, more reactors have to be constructed per year than historically achieved. Furthermore, it is important to realize that given the assumed nuclear energy demand curves and nuclear reactor park shutdown profile, these peak values have to be realized in only 10 to 20 years from now, which was different in the past. Time can be bought by extending the lifetime of the current reactor park. This will lead to a shift in the peak workforce demand. However, life time extension will also lead to an additional workforce demand.

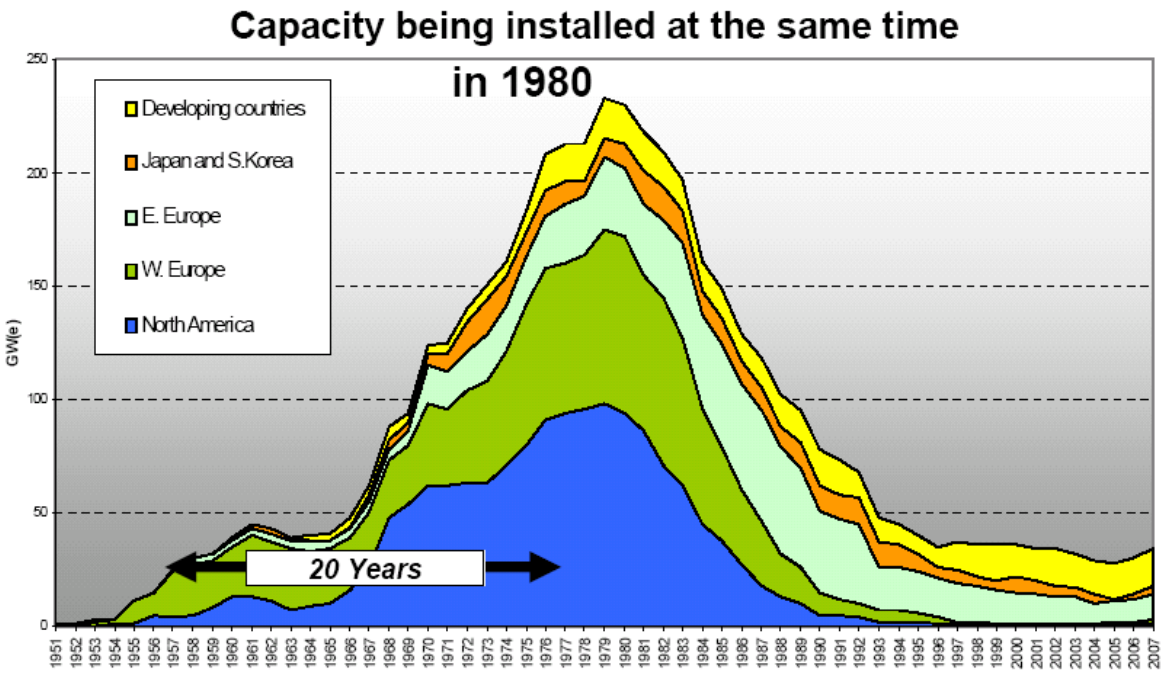

Figure 27: Historical IAEA data on capacity being installed at the same time (Hillrichs, 2009)

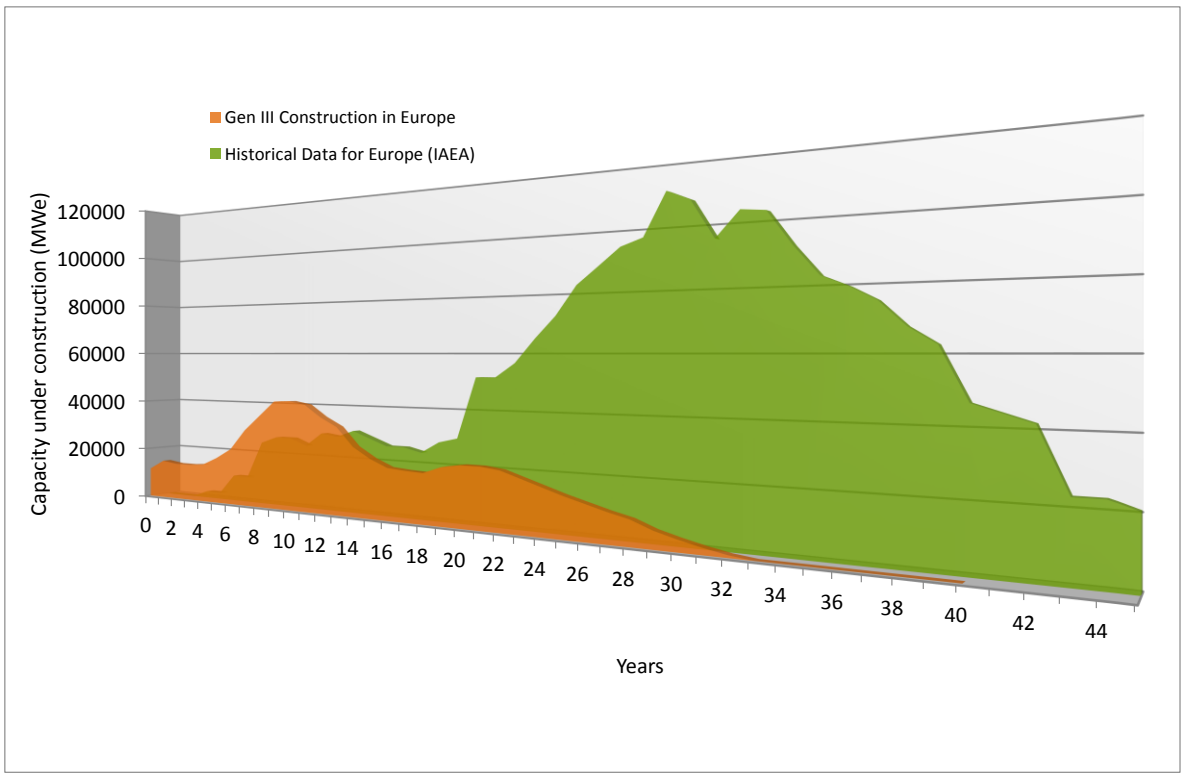

Figure 28: New workforce operations and construction for the EC Energy Roadmap 2050 (Case 1B)

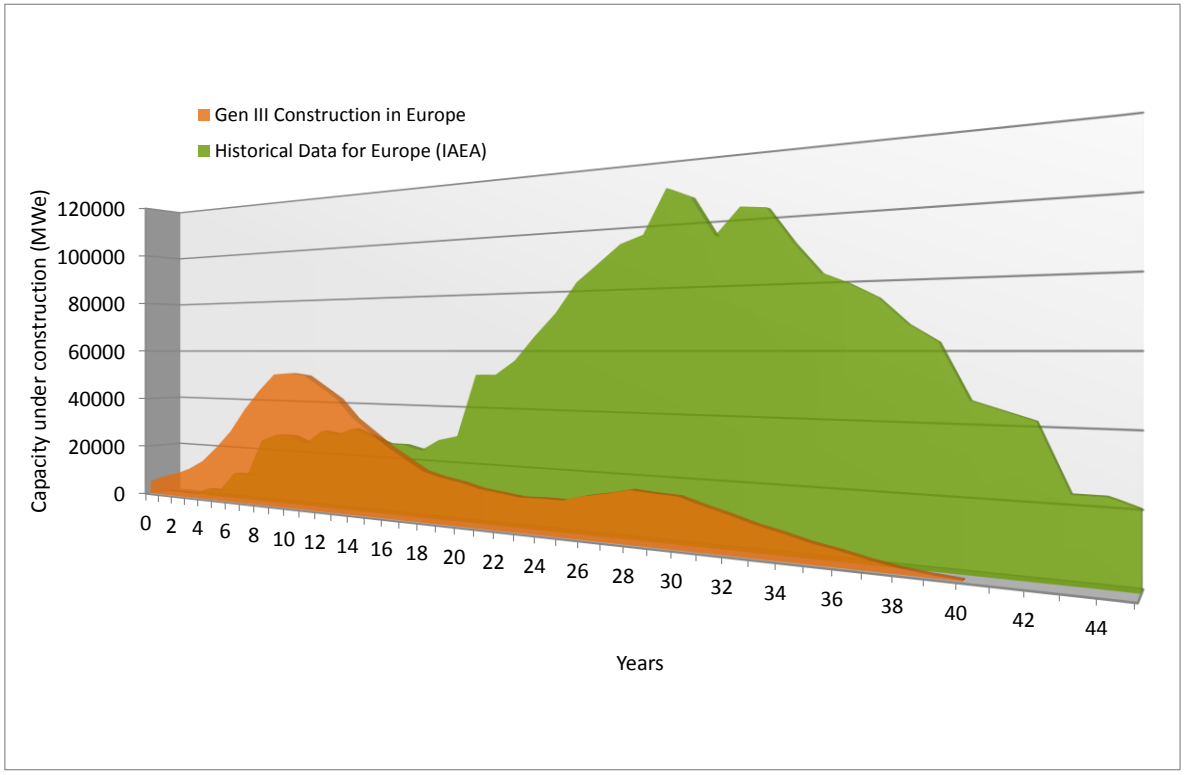

Figure 29: New workforce operations and construction for the OECD/IEA Technology Roadmap (Case 2A)

Conclusions

A top-down analysis has been made to derive figures for HR development under the assumption of two nuclear energy demand scenarios, i.e. the Delayed CCS scenario from the EC Energy Roadmap 2050 and the Blue Map scenario from the OECD/IEA Technology Roadmap. Both nuclear energy demand scenarios show a moderate growth of nuclear energy production in the EU27 countries including the integration and enlargement countries.

In the year 2010, about 140 nuclear reactors were operational within these countries with an average capacity of about 900 MWe. The analysed scenarios show that depending on the nuclear energy demand scenario and on the reactors sizes considered for new build, about 95 to 160 new reactors are required to fulfil the demand for nuclear energy.

Obviously, the workforce demand when relatively small reactors are considered for new build is larger than the workforce demand when relatively large reactors are considered for new build. Firstly, this is due to the fact that to fulfil the same energy demand, more small reactors need to be built than large reactors. Secondly, this is due to the fact the larger reactors require on average (per MWe installed) less workforce to operate the reactor the smaller reactors.

The total number of fte involved in construction of nuclear power plants equals ~50000 (70000 peak) for the scenario in which 160 reactors are constructed and ~20000 (40000 peak) for the scenario in which 95 reactors are constructed.

The new workforce is the workforce which partly has to replace the retiring workforce and which additionally has to keep up with the growing total workforce demand. From the analysis, the peak workforce demand for nuclear (experts), nuclearized, and nuclear aware can be determined. The peak workforce for nuclear experts is to be expected at the end of the considered period (2050) and amounts to about 7500-10000 nuclear experts. The peak workforce for nuclearized employees is also to be expected around 2050 and amounts to about 50000-65000 nuclearized employees. On the other hand, the peak workforce for nuclear aware employees is to be expected around 2020 and amounts to about 25000-50000 nuclear aware employees. Under the assumption of a typical amount of part-time contracts in the nuclear industry of about 5%, this relates to about 42500-80000 new jobs on the short term in 2020 and 67500 to 95000 jobs on the long term in 2050.

When comparing to historical data for the nuclear capacity being installed at the same time in Europe, it is clear that the expected future capacity to be installed at the same time in Europe is significantly lower (factor of 2) than in the early 1980's. However, it should be realized that the skills demand might have been more relaxed in those days. Furthermore, a steep rise in construction is to be expected within 10 to 15 years. This is due to the fact that not only additional nuclear power plants need to be built to keep up with the growing nuclear energy demand, but also to replace the current reactor park. Extending the lifetime of the current reactor park will lead to a shift in the peak workforce demand. However, life time extension will also lead to an additional workforce demand.

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Abstract

The EHRO-N team provides the EC with essential data related to supply and demand for nuclear experts based on bottom-up information from the nuclear industry. The current report deals with an alternative approach to derive figures for the demand side information of the nuclear workforce. Complementary to the bottom-up approach taken by the EHRO-N team at JRC-IET, a top-down modeling approach extrapolation of nuclear energy demand scenario's is followed here in addition to the survey information.
In this top-down modeling approach, well accepted nuclear energy demand data is used to derive the number of nuclear power plants that are in operation and under construction as a function of time from 2010 up to 2050 assuming that the current reactor park will be replaced by generic third generation reactors of 1400 MWe or 1000 MWe. Based on workforce models for operation and construction of nuclear power plants, the model allows a prediction of these respective workforces.

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