Peter Linnell   Is nuclear power a waste of talent?

The Human Resources implications of a new UK Nuclear Power programme compared with an emergent UK PV industry.

To persuade the UK electorate to accept new nuclear power stations it is claimed that "it will create jobs"; to claim these jobs are "high tech" is icing the cake. Opponents of nuclear power in the UK claim a greater number of jobs would be created by alternatives . This paper sets out to examine these conflicting claims in the light of a supply chain issue (human resources) arising from the recent announcements by HMG that it would look favourably on any proposals for new nuclear power plant to be built in the UK by the private sector.

The UK (and also US) nuclear industry is the most mature in global terms. There should be an established stream of training, development and succession able to cope with projects phased over two working generations or even longer. Whatever solution to meeting our electricity needs is adopted it will demand labour and materials. The issue here is what amount and quality of effort is specifically demanded by the nuclear option, and is it likely to be available in time.? New nuclear plant will be so called third generation designs incorporating features enhancing safety and simplified construction. Estimates of construction labour are shown in table 1(US DOE 2005). In addition highly qualified staff are required for ongoing operations for the life of the plant and beyond.(1)
(1.*numbered notes refer to appendix 1)*

Table 1. Peak On-Site Labor Requirements (Source US DOE 2005)

Personnel Description	Peak Personnel Average Single Plant	Peak Personnel Multiple Plants
Craft Labor	1600	8000
Craft Supervision	80	400
Site Indirect Labor	160	800
Quality Control Inspectors	40	200
NSSS Vendor and Subcontractor Staffs	140	700
EPC Contractor's Managers, Engineers, and Schedulers	100	500
Owner's O&M Staff	200	1000
Start-Up Personnel	60	300
NRC Inspectors	20	100

Total	2400	12000

Table 2 Operational staff numbers by qualification

<table>
<tr><th></th><th>Professional</th><th>Technical /Graduates</th><th>Craft and U/S</th></tr>
<tr><td>Operations</td><td></td><td>40</td><td rowspan="4">300</td></tr>
<tr><td>Technical</td><td rowspan="3">30</td><td>10</td></tr>
<tr><td>Maintenance</td><td>20</td></tr>
<tr><td>Safety</td><td>10</td></tr>
<tr><td>Total</td><td>30</td><td>80</td><td>300</td></tr>
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(Source; Watt 1984)

The UK nuclear industry presently (April 2008) employs some 40,000 people directly, broken down roughly into 20,000 in the fuel cycle, 9,000 in decommissioning and the remainder in power stations and generating related tasks (SDC March 2006)(2). The nuclear generator British Energy employs just over 6,000 staff directly, but in response to questions on the qualifications and demographic structure of staff BE declined to supply the information.(3) BE claimed to be able to fill all vacancies at craft apprenticeship and graduate level from 10,000 applicants per year. (BE recruitment.) From BE recruitment's own website they require honours graduates at 2.2 grade or above in Science, Technology, Engineering and Maths (STEM) subjects. In addition to a first degree, BE staff undertake an industry specific two year training period within the company with some content supplied by outside academic establishments.(BE website). In addition to it's graduate recruitment and training programme the company has a site based craft apprenticeship scheme providing industry specific skills in addition to traditional craft content provided by local CFEs.

Where are these staff going to come from.? Table 3 shows the number of STEM subject graduates in the fields required to construct and operate nuclear power stations as well as the fuel cycle and de-commissioning task.

Table 3. UK Graduates in relevant STEM subjects

Subject	Ac. Year 95/96	Ac. Year 2004/05
All	*251,248*	*306,365*
Computer Science	9212	20,095
Mathematical Science	4068	5270
Electrical & Electronic Engineering	5105	5630
Physics	1998	2235
Mechanical Engineering	3673	3400
Civil Engineering	3281	2515
Building Science	4275	2580

Chemistry	4144	2710
Chemical/Process Engineering	1221	770

(Source www.prospects.ac.uk)

Note that this data takes no account of country of origin or domicile of students. The UK is recognised globally as an excellent location for higher education, it must be allowed that a significant minority of these totals will include graduates who will not be available to the UK labour market. Data from HESA suggest the proportion is even higher for post graduate and research level qualified staff and greatest in STEM subjects. (DTI March 2006)(4)

This graduates pool is the total available to all UK industries from UK higher education, and from it must come future teachers at lower levels as well as post graduate degree students and researchers. From these data it can be concluded that the UK is struggling to provide suitably qualified entry level staff to the nuclear industry, so can the industry provide the staff required for expansion from within ?

Following privatisation of nuclear power stations as British Energy in 1996 there was for the first time a critical business level examination of staffing costs.

As a direct consequence of this the company instituted a programme of reduction in staff. By 1999 concerns within the industry about consequences of this programme for remaining staff led to intervention by the Nuclear Installations Inspectorate (NII 1999) . For clarity it must be pointed out that the NII is staffed by former workers at high management and skill levels from all sectors of the nuclear industry and they are uniquely qualified to examine the potential consequences of changes in work methods and staff practices. The report into the audit of BE is available in full on the NII website but here are some of it's key findings relating to numbers of qualified staff which convey the flavour.

> "*In BE(GL), we found no formal process by which the minimum skills base had been established (ie that which must be retained within the Licensee to enable it to discharge its duties under the licence). Thus the downsizing exercise was taking place without knowing the minimum resource requirements, or having a process to ensure they can be sustained over time. This has resulted in specialist expertise in several key areas (specific to the nuclear industry) being vested in single experts. Staff leaving to pursue their careers elsewhere have exacerbated this position since BEGL cannot easily find replacements with the requisite expertise and experience"*
> (NII 1999; *Executive Summary*)

> *"a requirement to 'provide a trained replacement before release ' becomes simply 'provide training'. The small sample of records that we checked did not provide confidence that the principles of the process had been honoured and the procedure followed rigorously. In our view a management of change process which can reduce a scarce resource down to a single person must, in any case, be open to question."*
> (NII 1999; *Section 58*)

The report, whilst expressing concerns about day to day working was able to support continuing operations (with suggestions for remedial changes). It was seriously critical of the long term position.(5)

Since this report in 1999 the industry as a whole has had some time in which to address the issues raised and steps have been taken including links to academic centres with relevant high quality expertise. The National Skills Academy for Nuclear (NSAN) was launched in October 2006 and a group of Universities, together with the industry has formed the Nuclear Technology Education Consortium to provide Masters and Doctorate level training.
Similarly the R&D functions of the fuel cycle industry have been devolved to the new National Nuclear Laboratory at the Sellafield site. It is unclear how much this points to new training capacity and how much is a concentration of previously dispersed effort; but it is true to say that these new umbrella training systems are able to focus government funding and better able to produce outcomes relevant to the nuclear industry's needs.
It is too early to quantify the output of this new regime, but we can examine the scale of the task as presently perceived, and also the lessons of history. Firstly, the Energy White Paper of 2007 identifies a need for 20 to 25 GW of new capacity by 2020. This serves to replace both the existing nuclear fleet and older coal burning plant as well as meet anticipated increases in demand. (EWP 2007). As outlined above a single new nuclear station would expect to provide 1GW(electrical) of capacity, take 500 staff to operate and 2500-5000 staff to construct. This would represent 2% of the UK construction capacity and a single plant would be well within normal fluctuations in conventional supply chain effort.(DTI May 2007; 11.14) It is also the case that the UK no longer has the capacity to manufacture new thermal generating plant so either this industry needs to be restarted or the plant imported. (Ditto;11.22)

In the DTI paper of May 2007 “The Role of Nuclear Power in a low Carbon Economy” the point is made that -

> *“there is a lack of staff aged 28 to 45 who are essential for long term sustainability of the skills pool”.*

In the responses to the Dpt. of Business, Enterprise and Regulatory Reform (BERR) consultation paper “Meeting the Energy Challenge- The Future of Nuclear Power;Analysis of consultation responses (Jan 2008) there is a telling comment attributed to an unnamed participant at the ministerial round table -

> *“I think we face...concerns around both engineering capability in the UK and maintenance and operational capability”*

Sir Peter Williams, Vice President of the Royal Society is quoted in Education Guardian (Jan 16th 2008) in an article responding to above white paper -

> *“We have to face the fact that we just wont be able to train people in time and we will have to look overseas to get this expertise”*

In the same article Peter Main, director of education and science at the Institute of Physics is quoted as reporting that we need-

> *“an additional 1,500 skilled staff **per year** just to complete decommissioning”* (emphasis mine)

Whilst the above comments relate to nuclear specific issues, there are wider concerns. W.K. Reder, writing for the Institute of Electrical and Electronic Engineers (Reder 2006) says-

> *“The industry faces a technical talent challenge... action must be taken to mitigate the effect of attrition in order to maintain the viability of the infrastructure.”*

There is a serious shortage of UK talent in the disciplines and craft skills needed by the existing nuclear industry. Resources have been positioned to address the identified shortages but have yet to deliver results, even so there is no guarantee that these measures will work at the required level. History suggests that caution is called for. During the age of Harold Wilson's “white heat of technology” large sums were invested in STEM subjects facilities at UK universities but failed to deliver their intended outputs. (6) It is true that if the private sector does decide to build new nuclear plant in the UK it will certainly create jobs. It is also certain that those jobs would largely be filled from outside the UK, as would the greatest part of the engineered components.

Would an effort in PV create jobs which can be filled?

For comparison consider the UK Photovoltaic industry. Because of impacts of support regimes operating in different countries the UK PV market is a pale shadow of that in Germany. However facilities exist in the UK to make crystalline silicon ingots, the feedstock for the wafers from which PV panels are assembled, at the rate of about 2,000 Tonnes per year. At present the majority of this output is supplied to Japan which is also a PV market on a similar scale to Germany. A number of factories exist in the UK producing PV panels, in a range of technologies including both amorphous and polycrystalline silicon.(7)

The Oxford based silicon ingot manufacturer PV Crystalox makes an interesting case study.

The company employs 85 staff at the site of whom 10% (8) are graduates, producing roughly 2,000 Tonnes of silicon ingots per year. (Personal Communication April 23 2008). Using the predicted yield of 6.8g per Watt by 2011 (Rogol, Flynn, October 2007) this reveals that this plant will be providing the feedstock for manufacturing between 250 and 300 MWp of PV panels every year. Sharp Manufacturing employs 550 on it's PV module assembly line at Wrexham with a line capacity of 4,000 panels per day or 230 MWp of capacity per year. Line jobs do not require graduate level skills, staff are tested for basic aptitudes and require little training. The company were unwilling to discuss expansion plans but also claimed to have no difficulties recruiting staff, relying on agencies for flexibility. (Personal Communication April 22nd.2008).

Combining these two companies productivity begins to provide a ball park estimate of skills required per GW of capacity. Here I am both ignoring raw material to the Oxford plant and assuming that the highly automated additional processing between ingot and panel assembly (which are not available in the UK) utilise approximately half the staff of the Oxford plant. (Based on an estimate supplied by a Crystalox employee).

Total output 230 MWp per year		Convert to GWp x 4.35	
Graduate staff	12	52	
Other staff	668	2,906	(8)

This does not include labour in installation. Steve Wade of Wind and Sun Ltd. (Personal Interview April 21 2008) gives an insight into the PV installation and end user market in the UK. The required skillset for installations is technical trade, with regulations for PV installations incorporated into the IEEC codes (17th Edition) any certificated UK electrician is qualified. From personal experience I can say that skilled electricians working in gangs with lower skilled help can multiply productivity for larger jobs. Many SME electrical businesses have trained staff specifically in these technologies to be listed for grant work, despite the changes in the support scheme which have largely removed this work. New building regulations requiring new housing to provide a proportion of its electricity needs from on site renewables will easily absorb this slack when such installations become routine. Once the PV is installed no further labour input is required (other than visits from the window cleaner).

We can claim with confidence that investment in PV will produce a reasonable balance of employments,(9) and raising production capacity to the scale of GWp per year is possible within the UK subject to investment and commercial requirements (existing contracts for example). Note here that this capacity is the resource to produce power generating resources, so the peak power available will rise by this amount every year. To put this another way, if the existing UK capacities were scaled up by a factor of four to 1GWp per year and the resulting panels installed in the UK then in 10 years the installed output would (at nominal peak) exceed that of the present nuclear fleet. (NB I am *not* suggesting it would replace total output in Gwh).

Conclusions

The UK has a crisis in STEM subject education, which has led to a skills crisis in the existing nuclear industry. Steps taken to overcome shortages have yet to show evidence of success (ten years after the NII audit). It is irrational to claim that a problem is solved by pointing to the effort being made to solve it (cf. Fusion power). The precautionary principle suggests newly qualified nuclear expertise be prioritised to waste management and decommissioning.

First blush examination of existing UK capacity suggests a multi GWp capacity in PV could be achieved without adverse skills impacts. To expand the nuclear industry by recruiting skills from overseas may be an option, if politically acceptable. Any claim that the nuclear industry will create significant additional high tech jobs for the UK is challenged. In terms of political/investment choices for new UK generating capacity nuclear demands a more concentrated application of scarce skills for a far greater time before any power is actually produced, and continues to make demands into an indefinite future.

Appendix 1 Outstanding questions and issues arising

1. Plant construction workforce breakdown. The data are from the US Dpt of Energy paper and are based on single plant and ten plant programme (10 GW capacity). As third generation plant will follow an internationally agreed design and construction method it is safe to assume these figures are valid estimates for a UK case. Construction workforce requirements would be raised by more rigorous H&S practices, but lowered by better modularisation and work planning.

2. The size of the present workforce is an estimate. Other sources give higher numbers, or take indirect and induced jobs into consideration.

3. I was unable to obtain a breakdown for operations and maintenance staff. This could be guestimated from analysis of recruitment operations, but this would only yield evidence of current gaps. The figures in table 2 are from 1984, but there is no evidence to suggest reductions in staffing requirements have been achieved since.

4. Some hard data on retention within the UK of the STEM subject graduates, regardless of origin, would be helpful. It may be available by examining raw data from DTI and HESA sources. The industry sees itself as global and would have no problem recruiting suitable talent from any source. France, Japan and Iran are all mentioned in sources.

5. I have not yet been able to find any subsequent or follow up reports from the NII on this specific matter.

6. Data on the STEM subjects effort from the 1960's proved hard to find. An initial trawl on-line provided hints of this concern going back to the mid 1940's. A statistical inspection of the impact of the 1960's effort would help in assessing the likely impact of the effort being made now. Detailed polling of A level students on career path and subject choice may yield sufficient facts to design an appropriate response. Industry is already using golden carrot methods to recruit STEM subject undergraduates.

7. Gaps exist in the PV supply chain notably in wafer and cell production. Both of these are highly automated and require a small number of highly skilled staff. The main barrier to entry is the high capital cost coupled with the ever improving efficiency of plant and processes. rigorous study of the complete supply chain from mineral to PV panel including labour, finance, materials, energy and plant would be useful. One report on the Chinese effort was found, but priced at e1k.

8. A similar examination of other UK players would permit a finer analysis, especially in terms of different technologies such as aSi and integrated PV systems.

9. A similar analysis of other renewable and energy saving strategies would be useful. Wind is semi-mature in UK but a mature industry in EU, offshore wind is an ideal opportunity for UK businesses established in offshore engineering. Similarly for emergent tidal current turbine technology. Energy saving measures including retro-fit provide large numbers of opportunities at the lowest skills investment levels.

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