sustainable development commission

The role of nuclear power in a low carbon economy

Paper 3:
Landscape, environment and community impacts of nuclear power

An evidence-based report by the Sustainable Development Commission

March 2006

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1 INTRODUCTION

Visual and landscape impacts are not often at the forefront of the nuclear power debate. Safety concerns and economics provoke greater concern than these environmental impacts, which are more often associated with renewable technologies.

Nevertheless, the environmental 'footprint' of nuclear power is an important consideration, related to the trade-off between loss of amenity and environmental damage and efforts to ensure security of supply in a low carbon economy.

Updating the UK's nuclear portfolio, by either 'replacing nuclear with nuclear' or engaging in a long-term expansion programme will have effects on both the landscape and local communities. However the extent of these impacts relative to other energy sources, and the technological improvements of new designs must be considered to determine the potential for nuclear power. It is necessary to consider all stages of the fuel cycle and the general effects each has on the environment.

This report outlines the main general impacts of nuclear power on the environment especially landscape, communities and employment. The paper focuses on the environmental and social impacts of uranium mining, processing and the operation of nuclear power stations. The use of coal, gas and oil is also associated with a range of social and environmental concerns, although they are not discussed here.

A summary of the environment and community impacts of nuclear power is provided in Table 1 (p. 12).

2 LANDSCAPE IMPACTS

2.1 Mining

Mining is the dominant landscape impact from nuclear power. Although there are no uranium reserves in the UK and most is extracted from Australia, Canada and parts of central Asia[i], it is important from a sustainable development perspective to recognize the landscape and community impacts of this activity wherever it occurs as part of the environmental footprint of nuclear power[ii].

There are four methods of uranium ore extraction:

a) open cut
b) underground
c) in-situ leaching (ISL)
d) as a by-product of other processes (e.g. gold mining)

In many respects the environmental impacts of a uranium mine are similar to those of metalliferous mining, its land-take depending on the concentration of ore. But the radioactive content of waste materials (e.g. spoils and tailings[iii]) is a significant difference. Underground extraction is the most commonly used technique. In-situ leaching[iv] is widely used as a low cost method and has the least visible landscape impact, but groundwater rehabilitation and pollution can be a concern. There are significant legacy issues including aquifer pollution in countries of the Former Soviet Union and Central and Eastern Europe.

Mining occupies approximately 20-50 hectares of land (0.08 - 0.2km^2) depending on the technique, with 1/3 of the occupied land from underground extraction disturbed. For open cut mining in Australia, approximately 3.5 times as much overburden is produced than ore[1]. In some cases, the overburden can be used in construction. Most of the land needed in the milling process is for the creation of a tailings pond (30-70 acres), where the non-uranium radioactive residues are disposed. In the short term this land is likely to be sterilised for productive and amenity uses due to radioactivity.

After decommissioning, most of a mine and milling site is reclaimable. More and more, the extraction of ores, site management, restoration and aftercare are carried out to international environmental standards to bring the land back into productive and amenity use. For example, an open cut extraction can be turned into a lake as with conventional quarries. Equipment and buildings must typically be removed and disposed of appropriately. For underground extraction, tailings are often returned to the pit and the entrance sealed and vegetated. Mary Kathleen in Australia was a major mine rehabilitation project, involving the plant site, a 28ha tailings dam, and a 60ha evaporation pond being returned to a cattle station with unrestricted access[2].

In the future, mining could occupy greater expanses of land (over 1km^2) as the concentrated reserves are depleted. However, the discovery of new, high concentration reserve could result in little difference in the land area required for extraction.

The text above draws mainly on industry sources (e.g. Uranium Information Centre).

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[i] The availability of uranium is dealt with in a separate report.
[ii] A comparison of the landscape and environmental impacts of different fuel sources can be found on P.60 of 'Wind Power in the UK', a previous publication by the Sustainable Development Commission.
[iii] these are the sands left after uranium has been chemically removed
[iv] this technique involves using acid or alkaline solutions to leach out uranium from highly porous deposits, such as sands, underground

Others cite concerns with regulation and land ownership issues, for example key concerns of an Australian Senate Committee Inquiry[v] (2003) into the regulation of four major uranium mines were:

- The exclusion of traditional owners over the management and protection of their lands including site selection, and ongoing environmental regulation, monitoring and reporting. Traditional land ownership rights and low price of uranium were given by Rio Tinto Zinc as reasons for lack of further development of the Jabiluka Mine in the Northern Territories;
- The need to review a complex regulatory regime to clarify roles and responsibilities, including whether the extent of self-regulation is appropriate;
- Ongoing pollution issues. In the Northern Territories the mines are upstream of the complex aquatic environment of the Kakadu World Heritage Site (also an international wetland site under the Ramsar convention), and pollution can be particularly difficult to manage during heavy seasonal rains. In 2000 an International Science Panel recommended a much tighter environmental monitoring regime to assess the risk of uranium mining on the World Heritage Site;
- Rehabilitation remains problematic - with the need to isolate run-off from tailings for up to 10,000 years;
- Problems with the in-situ leaching mining technique carried out at the Honeymoon and Beverley Mines in South Australia - raising concerns about groundwater pollution especially if aquifer systems are connected.

These findings have yet to be implemented. Given that uranium extraction in Australia is relatively well regulated, these findings raise concerns about the potential environmental impacts of uranium extraction in other countries, especially developing countries. It can be difficult for developing countries to put in place sophisticated regulatory regimes to govern the range of potential environmental and cultural impacts arising from a variety of economic activities, for a variety of reasons including:

- costs, which may be disproportionate in some cases or represent a significant 'opportunity cost' in relation to other pressing needs
- possible conflict with development aims
- lack of appropriate skills and expertise
- ineffective governance and corruption

This can result in products being brought to world markets at prices that do not reflect the full social and environmental costs of their production. The governance arrangements within countries are key to making sure that regulatory regimes distribute the costs and benefits associated with economic activity, including uranium extraction, fairly both for current generations and between current and future generations.

2.2 Fuel processing

Unlike mining, fuel processing activities (which include enrichment, fabrication, and conversion) are undertaken in the UK and have a much lower land-take, most of which can also be reclaimed.

The total area occupied by all of the sites for enrichment, conversion, fabrication, spent fuel storage and reprocessing facilities comprises about 385 hectares in total or 3.85km^2.

During enrichment, it is estimated that 1% of the site is committed to the storage of waste, and 10% for roads and the plant itself. Cooling towers must also be built if

[v] Australian Senate Committee Inquiry (2003) Regulating the Ranger, Jabiluka, Beverley and Honeymoon uranium mines

enrichment is performed using gaseous diffusion.

The Capenhurst enrichment facility in the UK occupies a 40ha site (about 0.4km^2.). At the fabrication facility, there are no long-term landscape impacts except for the small, contaminated holding ponds. Both fabrication and conversion facilities in the UK are located at Springfields, Lancashire, comprising 63 hectares of land. Similarly, reprocessing facilities can be decontaminated to a very low level, as 95% of the land at these sites acts as an undisturbed buffer zone.

2.3 Electricity generation

The land area required by nuclear power plants is comparable to that for coal- and gas- fired stations and around the same as that required by on-shore wind power. Other renewable technologies have very different land-take requirements, which may depend on how and where they are cited. For example, solar photovoltaics could be said to have zero land-take if installed on buildings, but quite a substantial requirement if installed as a 'solar park'.

It is estimated that the total land-take for a 1000MW nuclear power plant is between 100 and 400ha[3]. In comparison, we have estimated that the land-take for onshore wind power is around 180ha for 1000MW of capacity[4]. Others have suggested that the land-take from wind is much higher (usually by including the whole site), but as we stated in our report, it is only reasonable to include the land requirements of the turbine, access roads and substations, as the surrounding land is still accessible for other activities.

Nuclear land requirements will be the highest during the construction phase of a plant, when aggregates for road and plant construction are extracted and new transmission lines installed, in common with any large-scale electricity generating technology. Although plants vary in terms of their layout and reactor type, the same generic buildings tend to characterise most sites:

- reactor buildings
- turbine buildings
- main control building
- service building
- maintenance building
- cooling water pumphouse or cooling tower
- service water pump-house
- generator buildings
- water treatment facility
- main switchyard
- auxiliary & ancillary service buildings

Most plants are surrounded by an exclusion zone of anything between 500m and 1,500m, depending on land prices, land availability and reactor size. However, not all of the land within the exclusion zone is necessarily unproductive. It can be used for pastoral farming or as a wild refuge, depending on security issues. The principle of restricting access can be beneficial to the environment, acting as buffer zones supporting eco-systems[5].

In the UK, some coastal sites may not be suitable for new nuclear power stations and flood-risk criteria may lead to a preference for new inland sites. This is because of the need to 'climate change-proof' decisions about where to locate new plant to make sure they take into account changes in climate that are already in the pipeline. Nirex[vi] undertook some work for the CoRWM on the likelihood that surface or shallow storage facilities at current sites could be compromised as a result of the effects of climate change. The criteria that were used to select the current mainly coastal locations

[vi] UK NIREX Ltd (2005) Summary Note for CoRWM on the Impact of Rising Sea Levels on Coastal Sites with Radioactive Waste Stores

are up to 50 years old and will need to be reviewed, as many nuclear power stations and other facilities are vulnerable to sea-level change, storms and coastal erosion over the next several decades and up to 300 years. This could raise planning concerns, affect new communities of interest and delay the implementation of any new build programme, which is currently based on re-using existing sites because they are likely to be less controversial than new sites.

The Nirex study examined the likelihood of sea level rise using the current scenarios prepared by the UK Climate Impacts Programme (which are, in turn, based on the IPCC Third Assessment Report). The study looked at the likelihood of inundation associated with sea level rise, as well as flooding from storm surges and tsunamis, taking into account local geological and geomorphological factors to assess the vulnerability of sites to coastal erosion. The study notes that while the effects of sea level variations can be mitigated by the presence of coastal protection structures, it is generally accepted that these structures can only protect targeted sections of the coast in the short term, but may cause more erosion in the longer term. Ten sites were selected for detailed study on the basis of proximity to the coast and height above sea level. The potential that they could be compromised in the next 300 years is considered to be 'high' or 'very high' for 5 of the sites.

2.4 Reprocessing

Current indications are that the UK's Thermal Oxide Reprocessing Plant (THORP) at Sellafield is likely to be decommissioned and reclaimed from around 2010. Here, the spent fuel storage pools will be the main obstacle to reclamation to full productive or amenity uses.

2.5 Total land-take of nuclear power

Consistent with the analysis above, which draws on a variety of sources, the World Nuclear Association claims that the total land requirement for 1,000MW of nuclear capacity, including mining and the fuel cycle, is between 100 and 1,000ha[6].

2.6 Transmission lines

The impact of transmission lines on the landscape apply to all centralised electricity generating sources and are not particular to nuclear. The land requirement for the transmission corridor can stretch to over 60km, depending on the proximity to a load centre. However, the land either side of the pylons is available for alternative land uses, such as low intensity farming or wildlife corridors and does not affect transport routes.

The main impact of transmission lines is aesthetic. They are often prominent features in the landscape. Other considerations include potential impact on habitats (for example fragmenting woodland), communications, human health or carbon emissions through transmission losses. Impacts on habitats can be positively managed[7], for example by agreements on species composition and management between conservation agencies and the National Grid Company.

Nuclear power plants themselves have some flexibility in terms of where they are sited (more than hydropower for example), but the requirement for large volumes of cooling water tends to favour coastal locations. Public acceptability issues and site-specific environmental concerns often constrain possible locations. As a result, with one or two exceptions, most of the UK's current nuclear plants are in relatively remote locations, and transmission is therefore an important element.

2.7 Visual effect

The visual effect of the plant is the appearance of the facility relative to the landscape and people. Like other major industrial developments the main considerations are siting and design, the existing landscape and the response of local people to the proposed changes in the landscape[8].

Buildings and cooling towers can be up to 60 metres high changing the character of the landscape. The AP1000 containment building about 234 feet (71m) high[9]. As with wind power, it is possible to map the zone of visual influence (ZVI)[10] around the plant, and apply mitigation measures to mute visual impacts.

Light pollution may be an important consideration in some rural or protected areas. Some of these effects can be very difficult to quantify, but they are routinely assessed through Environmental Impact Assessments as part of the planning system.

3 OTHER ENVIRONMENTAL IMPACTS

3.1 Water use

All thermal plant, whether coal, gas or nuclear, requires substantial volumes of water for cooling. Discharges can lead to evaporation and cloud formation. Without careful management, water intake can lead to fish and other aquatic species mortality.

One study[11] finds that 570 million fish longer than 3cm are killed each year in 33 power stations in the UK and Ireland. In addition to fish, larvae and eggs can be sucked through condenser circuits and subject to heat, pressure changes and chlorination before being returned to the sea. New technologies designed to eliminate these adverse effects are available.

3.2 Thermal discharge

In addition to the materials used for construction of the plant and its infrastructure, natural resources are consumed during operation. The largest of these is water, used in the plant as a coolant. It is estimated older plants need about 40-60m^3 per second of water, the same requirement as a city the size of Chicago. The Energy Working Group[12] put this figure at between 3,000 and 5,000m^3 per GW of electricity, with an additional on-consumptive use of 986,000m^3. Most of the intake water after screening is used as once-through cooling water for the condensers and can be discharged up to 10ºC warmer. The level of this thermal discharge depends upon the thermal efficiency of the plant and the type of cooling system adopted. Large temperature differences between the discharged water and ambient water temperatures, together with changes in salinity, can lead to the loss of some species and habitats. Elevated temperatures may assist some intensive uses, such as some forms of aquaculture around plants in France and Japan. There is also potential for the waste heat to be used for residential and industrial heating and air conditioning, for example in parts of Sweden, Finland, France, the USA and Germany.

3.3 Waste

The issue of waste, both legacy waste from decommissioned reactors and that which would be produced with replacement or new build is dealt with in a separate report. Here, we briefly note that land requirements for spent fuel are not considered to be large. Options for long-term management of radioactive wastes are currently being considered by the Committee on Radioactive Waste Management, due to report its findings to Government in July 2006. As with the original plant, any above-ground infrastructure associated with the management of radioactive wastes should be sited and designed so as to be sympathetic to the character of the local landscape, and should not, as far as possible, detract from public access to the countryside.

4 COMMUNITY AND EMPLOYMENT IMPACTS

4.1 Community impacts

For the UK, community impacts are discussed in more detail in Paper 7 – *Public perceptions and community issues*.

Other social impacts of plant construction might include the negative image effect of nuclear power and perceived safety concerns, which may lead to a depression in house prices, changes in tourism or investment. Changes to community character may also occur with anxiety or divided opinions on a project. Alternatively, the community can be revived via direct and indirect investment in existing infrastructure like roads, railways, schools and health centres and through cultural diversity.

The most intense socio-economic activity is likely to occur during the construction and operation of the plant. Following decommissioning, community dynamics are likely to change again. But unlike many major industrial activities these changes can be anticipated and managed to minimise any adverse impacts.

Note that the costs and benefits for employment and other community impacts should be assessed for the overall portfolio of measures adopted in a wider energy policy rather than with regard to one sector alone.

There are also community impacts associated with the nuclear fuel cycle in other countries, for example in Australia where the 'national interest' can be invoked to veto traditional land ownership rights. This has led to Aboriginal groups being excluded from consultations about developments on their land, and from subsequent environmental regulation, monitoring and reporting regimes. See footnote v for further discussion.

4.2 Employment impacts

Most of the sources on this subject are industry-linked and may be subject to some 'optimism bias'. Further, all forms of electricity supply will bring employment benefits, although they will differ in skill sets and distribution (both by sector and geography) for different technologies. As such, it is difficult to assess the net employment benefits or community impacts for one technology in isolation: it is more meaningful to evaluate the impact of a portfolio of measures.

Almost 40,000 people are directly employed by the UK nuclear industry, with almost as many again indirectly dependent upon it. About 20,000 are said to be involved in the production, reprocessing and storage of nuclear fuel, with 15,000 employed in the operation and decommissioning of plants[13]. Many of the jobs are high skilled, well paid and often in areas where alternative employment opportunities are low. Job losses from plant closure can be partly offset by decommissioning employment although economic activity in the local area will eventually decline.

The siting, construction and operation of any major facility inevitably has both positive and negative impacts on the local economy. One of the primary local benefits for communities in the vicinity of a nuclear plant, is the creation of local jobs and the direct impacts of salary payments, business taxes and capital expenditure that come with employment. There may also be positive indirect impacts such as the development of local supply chains or improvements to infrastructure due to increased demand for services.

The significance of the employment impact will depend on the workforce catchment area, the proportion of locals employed, the skills requirements and the balance of job retention against job creation[14]. The influx of skilled workers and their families to the local community can create social and cultural tensions and pressure upon local services and infrastructure[15]. Past experience suggests that there is a trade-off between the benefits of local employment from nuclear power and the perceived negative image that deters alternative investment. In small communities with a less diverse economic base, the employment effects of a nuclear plant can be significant.

Two thirds of the residents of Sellafield are employed at the reprocessing plant, and most others rely indirectly on Sellafield's demand for services[16]. The UK company British Energy directly creates 4,900 jobs, most of which are at their eight nuclear plants[17] and an estimated 12,700 indirect and induced jobs[18]. Similarly, BNFL plc employs 23,000 people as a group, 16,000 in the UK mostly in the vicinity of its plants. Its Nuclear Sciences and Technology Services (Nexia) and Spent Fuel Services (SFS) employ 900 and 494 people respectively, with Westinghouse Electric providing 7,600 jobs worldwide[19]. Its older Magnox fleet employ, or have employed, on average 350 workers[20].

On a local scale, studies have indicated 5,000 jobs have been safeguarded in West Cumbria over the past six years as a result of BNFL community investment. At the peak of its operations in the early 1990s, the Sellafield site employed two thirds of local residents with almost all of the population indirectly dependent upon it[21].

However, as stated above, an attempt to measure the net employment impact of a new nuclear programme would need to take account of any substitution effect. This refers to employment that might have been created in alternative technologies and industries but which investment in nuclear plant could displace. Essentially there is an upper limit to the need for new electricity generating capacity, and each potential technology and industry would create some employment through meeting it.

Some renewable energy technologies (e.g. microgeneration) have a high potential for employment creation at many different levels. The DTI estimates that up to 35,000 jobs could be created in the renewables sector by 2020, up from around 8,000 currently[22].

Table 1: Environmental & community impacts of the fuel cycle

Fuel Type	Natural Environment	Community
Mining	**Land disturbance** ▪ **Radio-nuclide effluents** ▪ **Solid waste** ▪ **Tailings** **Water**	**Aesthetics** **Employment** **Health & safety**
Milling	**Land** **Tailings** **Radio-nuclides into air & water**	**Employment**
Conversion	**Land** **Thermal discharge** **Radio-nuclides release**	**Employment**
Enrichment	**Land** **Water** **Depleted uranium** **Transmission lines**	**Employment**
Fabrication	**Land** **Water**	**Employment**
Plant	**Land** **Water** **Thermal discharge**	**Aesthetics / image** **Demographic & cultural Change** **Employment**
Transmission Lines	**Land** **Wildlife**	**Aesthetics** **Safety**
Reprocessing	**Land** **Radioactive air & water emissions** **Solid waste**	**Employment**
Spent Fuel Disposal	**Land** **Water**	**Health & safety**
Decommissioning	**Land** **Air** **Water**	**Aesthetics** **Demographic & cultural Change**

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