European Nuclear Society – High Scientific Council

How Safe is Safe Enough in the Context of Nuclear Power?

Introduction

The cost of civil nuclear power for electricity production has increased significantly over recent years and, to some, the cost of nuclear power is rapidly becoming unaffordable. The increase in cost results from a number of reasons, notably the high cost of finance that is a consequence of high capital cost that is associated with the complexity and long build times of large nuclear power plants (NPPs) and the strict safety regulations imposed on the nuclear industry.[1] The requirement for complex control and protection systems, both passive and active, adds to the capital cost, as does the increasingly stringent security requirements. Safety is paramount and Europe continues to maintain high levels of nuclear safety. However, given the escalation in cost of new NPPs, the High Scientific Council of the European Nuclear Society (HSC) believes that it is timely to look at what safety means in the context of nuclear power.

The purpose of this paper is to examine the question "how safe is safe enough" in the context of nuclear power. It is aimed at the decision makers in government, the nuclear industry and the regulatory organisations. As a result of this work, the HSC would like to see an open discussion between the nuclear industry and its regulators on the appropriate levels of safety for new NPPs to ensure that they are not priced out of the market by marginal and perhaps unnecessary safety gains.

Safety and Risk

The question "how safe is safe enough?" is not easy to answer. The issue is complex and depends on our understanding of what we mean by "safety". Safety is often measured and judged in relation to risk, risk being the product of the chance of some adverse event happening (probability) and the impact of that event (consequence). Safety is relative: what is "safe" for one person may not be "safe" for another. For example, people who drive automobiles are willing to accept a risk of around $1x10^{-4}$ per year of being killed in a road accident because of the perceived benefit of personal transport. Yet some will often not accept the use of nuclear energy when the risk to them is much lower i.e. $1x10^{-6}$ – $1x10^{-7}$ per year of being killed as result of a nuclear accident. People who drive automobiles believe they are safe because they are in control and can manage the risk. Often, people are more cautious of activities when they are not in control, even if the risk is lower. An example of this is that some people often prefer to drive rather than fly, even though flying per mile is much safer than driving. The argument is that, when driving they think they are in control whilst in an aeroplane, they must rely on others. Often this inconsistency is driven by fear of an accident or a perceived threat to their health and hence the enjoyment of their future life. In the case of nuclear energy, people's risk perception is usually coloured by more

[1] Lurshina D, Karpov N, Kirkegaard M, and Semenov E; Why nuclear power plants cost so much and what can be done about it, Bulletin of the Atomic Scientists 2019

than a fear of not being in control, other factors such as the dread of contracting life-threatening cancers and the proliferation of nuclear weapons also play a part.

The risks people are prepared to accept or tolerate are often linked to the benefit they will receive by taking the risk. These are personal judgements, but sometimes societal risks require collective judgements. One of the major risks facing mankind now, whether in the developed or developing world, is climate change. If catastrophic climate change and global warming is to be avoided, mankind needs to find a reliable and proven low carbon energy solution quickly. Nuclear power is a proven and reliable low carbon technology, but it has failed to gain widespread public acceptance because of safety concerns and, to many in developing countries, it is simply unaffordable. If nuclear power is to have a role to play, it must be seen by the public to be both safe and affordable. At the very least, the public must be willing to tolerate the risks associated with the use of nuclear power, as they tolerate the risks from other industrial activities, in order to obtain improvements to living standards and lifestyles.

It must be recognised that a tolerable level of risk for the public to take is not necessarily the same as an acceptable level of risk. Tolerable implies a willingness to live with a level of risk to secure certain benefits, provided that the risk is being properly controlled. In the context of climate change, the risks associated with nuclear power could be tolerated in order to secure the benefit of nuclear power in the fight against the greater risk from climate change and limiting the rise in global temperatures to sustainable levels. Therefore, when asking the question “how safe is safe enough” in relation to nuclear power, it is important to view the risks associated with NPPs in the context of the risks to people’s health, living standards and lifestyles, and the degradation of the natural world, associated with failure to achieve the 2050 climate change targets if nuclear power was not part of the energy mix.

Safety and Regulation

When new technologies are introduced that have the potential to harm people, society usually requires such technologies to be regulated by their governments. Nuclear power is no exception. From its inception, it has been regulated in one form or another in all counties to protect both workers, the public and the environment. The release of radioactivity as a result of a nuclear accident can have trans-boundary effects and therefore there is also an extensive international framework governing the use of this technology. A cornerstone of both national and international requirements governing the use of nuclear power is that a practice that results in ionising radiation must be justified. It must be proved that the exposure of workers and the public to ionising radiation must be kept as low as is reasonably achievable (ALARA). Some countries use the term “as low as reasonably practicable” (ALARP). ALARA and ALARP can be considered to be equivalent. Both terms imply the use of cost benefit analysis to determine what is “reasonable”.

The risks associated with the use of nuclear power must be shown to meet the ALARA/ALARP requirements. However, evaluating what is reasonable to spend in order to reduce risk is key to the future of nuclear power. Hence, it is important to have a consistent approach to the interpretation ALARA/ALARP and how it is applied. The unconditional application of ALAR/ALARP can drive down risk at an ever-increasing cost and with marginal benefit. Therefore, to avoid unnecessary cost, the nuclear

industry and regulators (who act on behalf of the public) should agree clear safety objectives where the level of risk to both workers and the public are deemed to be acceptable / negligible. Once these objectives have been reached, no further expenditure should be required to reduce the risk beyond this level even though it may be technically possible.

Risk Assessment and Decision Making

Assessing risk and making judgements is common in many industries. A comparison of the risk targets used by various industries with high hazard potential suggests that the maximum individual risk target for members of the public is around $1x10^{-4}$ with the negligible risk target of around $1x10^{-6}$ / $1x10^{-7}$. However, it is important to recognize that, whilst the acceptability of the design of an NPP can be guided by risk analysis, it cannot be determined on the basis of numerical analysis alone. Good engineering design practices and sound judgement by licensees and regulators is also required. The UK documents on the Tolerability of Risk[2], Reducing Risk and Protecting People[3] and the ONR Safety Assessment Principles[4] give an insight into how judgements can be taken. Another approach is the "judgement value" or "J Value"[5]. The J value is a useful tool that can be used to make a judgement on how much to spend on safety and is based upon the benefit to be gained from a person's life to come.

How safe is safe enough?

In the nuclear and other high hazard potential industries, both "hard" (engineered systems) and "soft" (leadership, management and culture) approaches are used to ensure that the risks to workers and the public are acceptably low. Whilst the "soft" contributions are important to the delivery of safety, especially a just (no blame) culture within the industry and the regulators, it is the hard engineering that has the greatest impact on risk reduction and cost. The key question facing the nuclear industry is "what is an acceptably low level of risk". This is key because, without an agreed level of risk, the industry could become unaffordable as a result of the increasing cost of implementing ever more complex safety systems to meet what could be unjustifiable requirements.

Risk is the key to answering the question, and hence risk criteria are important to being able to make the judgements that are required. The analysis of risk in both the nuclear and other high hazard potential industries suggests there is surprising level of commonality when it comes to risk targets for both workers and the public. In line with this commonality, Table 1 below shows the High Scientific Council's proposed risk targets.

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[2] Health and Safety Executive, Tolerability of Risk from Nuclear Power Stations, HSE Books 1992, ISBN 0 1 1. 886368 1, www.onr.org.uk/documents/tolerabilty.pdf

[3] Health and Safety Executive, Reducing Risk, Protecting People, HSE Books, 2001 www.hse.gopv.uk/Risk/Theory/r2p2.pdf

[4] Office of Nuclear Regulation, Safety Assessment Principles for Nuclear Facilities, 2014, www.onr.org.uk/saps2014.pdf

[5] I. Waddington, P.J. Thomas, R.H. Taylor G.J. Vaughan, J Value assessment of relocation measures following the nuclear power plant accidents at Chernobyl and Fukushima Daiichi, Process Safety and Environmental Protection, 112(2017) p16-49

	Maximum Risk (per year)	Broadly Acceptable Risk (per year)
Worker (individual)	$1x10^{-3}$	$1x10^{-6}$
Public (individual)*	$1x10^{-4}$	$1x10^{-6}$
Public (individual)**	$1x\ 10^{-5}$	$1x10^{-7}$
Societal (100 fatalities)***	$1x10^{-5}$	$1x10^{-7}$

*existing NPPs, **new NPPs ***single event causing 100 or more fatalities

Table 1 Proposed Risk Targets for the Nuclear Industry

The High Scientific Council believes that it is important for the nuclear industry and its regulators to agree the level of risk to be delivered for all new NPPs. NPP designs that present risks greater than the maximum risk in Table 1 should not be constructed. The nuclear industry and its regulators should also agree on a broadly acceptable level of risk that new NPPs should deliver for both workers and the public. Spending to further reduce risks below the broadly acceptable would not be justified.

The desire for continuous improvement should not be used to drive risk below the broadly acceptable level unless the improvements are cost neutral. For new NPPs, the aim should be to ensure that the overall risk to the public should not increase and where practicable reduced in line with the ALARP/ALARA principle. The effective application of ALARP/ALARA depends on some form of cost benefit analysis and this can be controversial. The J-Value mentioned above is one approach to enable valued judgements to be made on how much should be spent to reduce a risk in the ALARP region. The nuclear industry and its regulators should agree on the cost-benefit analysis approach to be used to evaluate the benefits of risk reduction technologies in the design of new NPPs when risks are in the ALARP region.

Conclusions

The answer to the question “how safe is safe enough?” is not easy. It is recognised that, for some people, a nuclear power plant can never be safe enough and, as long as the risk perception of nuclear power is quite different from the real risk, it is unlikely to change these views on the acceptance of nuclear power. However, in spite of this, it is important not to lose sight of the benefits of nuclear power in the fight against climate change. The loss of nuclear power in the armory to fight climate change because it was unaffordable should not be allowed to happen.

The High Scientific Council recognises that, to answer the question ‘how safe is safe enough?”, it is necessary to look at the risks that people and societies are willing to accept or tolerate in order to have the benefits of a secure and prosperous life.

However, when agreeing what are acceptable/tolerable risks, care must be taken to ensure that the risk targets are well founded, and are not unrealistic or unjustifiable which would result in potentially unaffordable requirements being set for new NPPs.

The High Scientific Council believes that both the nuclear industry and its regulators should, as a matter of urgency, engage in a discussion with the public and key stakeholders including vendors, academia and other research organisations to answer the question of how safe is safe enough. This discussion should be set in the context of the essential contribution nuclear power can play in reducing the risk associated with the adverse consequences of climate change.

The High Scientific Council believes that the risk targets shown in Table 1 form a useful basis for the discussion on the safety requirements new NPPs.

The High Scientific Council also believes that the nuclear industry and its regulators should promote a "no blame, positive safety culture" in their organisations so that discussion on risk can be open and transparent and avoid measures/requirements that go beyond agreed safety objectives.