UNIVERSITY OF CAMBRIDGE
Electricity Policy Research Group

Energy Supply, Risk and Justice: Regulatory Strategies for an Era of Limited Trust

EPRG Working Paper 0807

John Stewart Ash

Abstract Regulatory organisations responsible for implementing safety in the civil energy sector must address a triad of factors. Namely, the risk tolerance of the community, the methodology used to measure and enforce risk levels, and the resources available to the regulatory agency. Attempts to balance these factors have often focussed on attempting to align public perceptions of risk with those of government personnel, technical specialists and industry. This "information deficit" approach has been largely unsuccessful because the shortfall, particularly in respect to dread risk, has not been one of knowledge, but of trust. Trust may be viewed as an expectation of just or fair treatment by others. To retain legitimacy, any government must act with justice. Justice has two related elements – distributive and retributive. This paper explores novel approaches to the achievement of both aspects of justice in order better to ensure the just apportionment of risk in energy safety regulation.

Keywords Energy, justice, regulation, risk, trust.

JEL Classification Q48, K23

EPRG WORKING PAPER

Contact jsa1003@cam.ac.uk
Publication In publication
Financial Support EPRG, TSEC3

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

1. Introduction

The avoidance of risk has become a preoccupying theme in modern society (Furedi, 1997). This concern has been reflected in many aspects of societal behaviour (*ibid.*) and has led to some severe challenges for government and the regulatory process. However, the severity of the expectations placed on the regulatory process by a risk averse culture, presents particular difficulties in respect to the provision of bulk electrical power in the United Kingdom.

The demand for electricity as it is distributed through the transmission network ('Grid') is typically some 40GW with peak requirements reaching 60GW (POST, 2007). This is supplied from some 30 large power stations each with an output exceeding 1GW (*ibid.*). By 2015, one third of the coal-fired stations and the majority of the nuclear plants will have closed, leaving a generation shortfall of some 15GW (*ibid.*). While government perception emphasises more efficient energy use (DTI, 2007 a), it views the remedy for the supply shortfall in two principal options; greater reliance on gas powered plant, which brings perceived security of supply issues, or the construction of a new fleet of nuclear power stations (DTI, 2007 b). The need for low Carbon generation processes and security of supply certainly favours source diversity into renewable technologies such as wind power. However, while rapidly developing in capacity and sophistication, renewable sources may be intermittent in capacity, often require very large geographical footprints and provide slow returns on investment capital. The result is that the nuclear option is receiving serious consideration (DTI, 2007 b) and if that option is to be realised, it will require sanction at three stages [i]. First, societal acceptance of the option in principle. Second, the licensing of plant and sites. The final stage is the post construction regulation of generating operations, maintenance and waste disposal. This paper considers the latter two stages as problems in regulation. In particular, it explores barriers to establishing and implementing shared values in risk tolerance, and how the principles of justice may be applied in the safety regulation of bulk electrical power sources to enhance trust. The argument does not favour nuclear or non-nuclear approaches to electricity generation.

2. Regulation as a practice

If risk is taken to be the likelihood of an undesired event, then one of the chief responsibilities of government is risk management. This responsibility varies from defence of the realm, or “protecting the society from violence and invasion of other independent societies” which, Adam Smith argues, is the first duty of the sovereign (Smith, 1776 republished 1904), to protection against the perils of disease and the natural world, criminal behaviour, extreme economic hardship and poor professional practice. In particular, the UK Government shoulders the responsibility for protecting British subjects from the perils they can neither defend themselves nor insure against on an individual basis.

Clearly, many of the perils that may afflict the ordinary citizen are often linked in a complex fashion, and the provision of bulk electrical power is an example of a societal good that both mitigates and creates potential and related hazards. People may at once fear a loss of electrical power, the effects of global warming, and any risks associated with living in the locality of power generating plant. The fact that such risks may place mitigating measures in opposition to each other does nothing to disprove their simultaneous reality, or their potential to visit individuals with unequal and severe levels of harm. Moreover, there is nothing illogical or irrational in the thoughtful individual being concerned with all three sets of risks at once, and expecting government protection from them, despite the conflicting demands such an expectation places on regulatory authorities.

In its broadest sense, all three branches of government; the executive, judiciary and legislature, play separate but critical roles in discharging this risk management duty. As Hawkins (1992) notes however, the business of policy implementation in governance, in particular, the necessary interpretation of laws undertaken by regulators, brings considerable flexibility to the process of decision making. Indeed, such flexibility in implementation may exceed a level that would be inferred from a textbook understanding of the law or constitution. In framing laws, the legislature cannot predict every eventuality demanding a regulatory judgement. In turn, the executive must use its discretion to apply legal rules to practical problems, and the judiciary interprets law only in those cases brought before it. This flexibility is an inevitable feature of the complex societal risk decision making process. It is also a key to solving the seemingly self-contradictory and irreconcilable demands raised by meeting the demand for bulk electricity supply.

From the perspective of the regulatory actor, as a sub-set of the entire network of decision making involved in energy related risk management, the duty of defending the public interest brings a requirement to address a triad of elements:

1. The risk tolerance of the community that is served.
2. The methodology used to measure and enforce tolerable risk levels.
3. The resources available to the regulatory agency.

These factors are dynamic and related (Figure 1). Societal risk tolerance levels are represented in codified law, although not always explicitly. A pertinent and simplified example would be the application of the law to the release of radioactive materials from nuclear power stations. The Radioactive Substances Act 1993 (RSA 1993) does not specify the degree of risk to which members of the public may be exposed in connection with radiation from industrial discharges. Instead, it apportions responsibility to the Environment Agency (EA) and Scottish Environment Protection Agency (SEPA) for authorising radioactive discharges and disposals from licensed sites (EA, 2004; RSA 1993). Those regulatory agencies are entitled to guidance on statutory objectives under the Environment Act 1995, and this was issued for England in draft form by the Department for the Environment, Transport and the Regions (DETR)[ii] in October 2000 (EA, 2004). This draft guidance, and its equivalent for Wales, enjoins the EA to identify and evaluate alternative measures to ensure that the Best Practicable Environmental Option (BPEO) [iii] is chosen prior to authorisations being granted (*ibid.*). It is left to the agencies themselves to identify appropriate numerical standards for risk. For example, in connection with nuclear power stations, the Health and Safety Executive

(HSE) uses a process of rendering risks ‘As Low As Reasonably Practicable’ (ALARP) within a region of tolerability benchmarked against a limit of 10^{-5} for any member of the public. This figure will be discussed further below.

Societal risk tolerance levels are also reflected in regulatory methodology and the resources necessary to bring about implementation. Regulators have a duty to interpret legislation and identify where particular development proposals and engineering designs fail to meet acceptable standards. They must also identify appropriate regulatory approaches and secure funds to meet risk tolerance expectations, knowing full well that any significant harms will reflect on their actions, as well as those of the regulated.

Following the view of industry held by Dunsire (1993), who cites the observations of Bardach and Kagan (1982) in respect of the United States, the majority of the regulation of bulk energy providers would appear to be internal. That is, it comprises professional and engineering standards that are accepted throughout a given industry or discipline and self-imposed by practitioners. This inference is supported not only by a simple comparison of the numbers of trained individuals employed by the industry against establishment levels in agencies such as the HSE’s Nuclear Directorate (BE, 2007; HSE, 2007), but also the fact that the agency’s own strategy is founded on principles designed to ensure that proper oversight, monitoring and audit of safety standards exist within companies (HSE, 2006). It is unrealistic to expect that external regulators will mimic all of the calculations and review every safety-critical decision made by an energy company to ensure acceptable standards. It is also unaffordable. Regulation is therefore inescapably a matter of compromise; a risk management exercise in itself.

[Figure 1 here].

An ideal world depiction of regulation would commence with a measurement of societal risk tolerance, followed by identification of the preferred methods to be applied in its achievement and thereafter a determination of the required resources to implement the programme. Such a linear model of regulatory practice resides firmly in the realm of the imagination. Even an iterative view of such an approach, in which the outcomes of the regulatory programme resulting from the chosen methods feed back into revised risk expectations, fails to capture the interdependence of the three elements. For this reason, Figure 1 depicts a fourth element in the centre of the triangle; the eventuation of hazards as perceived by all of the stakeholders, an element that itself affects and is affected by the other three.

While any one of the elements may be subject to unrealistic expectations, this paper particularly addresses the problem as it affects societal risk tolerance. Of course, even relatively modest risk management expectations may be impossible to meet in practice. For example, certain technologies may be ungovernable irrespective of the risk expectations or available resources, because no practical methodology exists to control them and their regulation is therefore a fruitless exercise. That would be an inference from Charles Perrow's theory of Normal Accidents, under which he includes civil nuclear power as a technology too vulnerable to unmanageable events to be tolerated (Perrow, 1984 reprinted 1999). In respect of resources, regulation can be highly specialised, and recruiting an appropriate number of regulatory staff may prove impractical even if generous funds are available. However, if tolerance levels are too demanding, no amount of funding or careful application may meet society's expectations. An example of societal intolerance of risk in relation to nuclear generation may be found in the management of radioactive waste. For over three decades, attempts to determine a solution to the problem of long-term radioactive waste management in the UK failed in the face of spirited resistance from trades unions, NGO members, local government coalitions, citizen protest movements and international protesters (CoRWM, 2006). This rejection of government and industry proposals, and by implication, their associated risk tolerance standards, emphasises the profoundly social, as well as technical aspects of the regulatory problem.

3. The information deficit approach and the failure of numbers

Previous attempts to address this issue have focussed on altering risk tolerance in the population, attempting to align public perception of risk with that of government personnel, technical specialists and industry. This has been the “information deficit” approach (Burgess et al., 1998). It is based on a belief that a process of education will dispel fear, or at least lead to public action that meets policy objectives (Eden, 1996). It has been largely unsuccessful (McKenzie-Mohr, 2000) because the significant shortfall, particularly in respect to the dread[iv] risk aspects of nuclear power, has not been one of knowledge but one of trust. Since the work of Starr in the late 1960s it has been known that risk tolerance is related to factors such as the late eventuation of hazards, their catastrophic potential, whether their risks are voluntarily assumed, and the extent to which such risks are equally distributed. As Dobson (1998) reminds us, in risk distribution, we must seek equity in the attribution of not only the benefits of a project or service but also its risks, since when we distribute the advantages, the hazards inevitably follow.

The distribution of hazards is of particular note in this paper. Sandman (1993) goes so far as to define risk (R) as a function of hazard (H) and something he terms ‘outrage’ (O):

$$R = f(H, O)$$

(Sandman, 1993) [v]

Sandman’s concept of outrage incorporates all of those factors that determine how the public usually assess risk; namely whether a risk is coerced, natural, familiar, memorable, dreaded, catastrophic, knowable, morally relevant, fairly distributed, and under the control of the potentially injured party (Sandman, 1993). Critically, Sandman also includes within the outrage factor whether the potentially injured party finds the administrative process responsive and trusts those involved (*ibid.*).

Cohn’s (1997) study of the societal factors underlying the development of the United States nuclear power programme in the 1950s and 1960s includes the faith citizens had in the capacity of technology to solve their problems, and in their leaders. Such belief has now dimmed both in North America and Europe. Numerical estimates of risk for comparative sources of bulk electrical power, such as those of Fremlin (1989), conspicuously favour nuclear power as a safe method of generation. Nuclear power also offers a means of mitigating carbon emissions to a level that rivals renewable energy sources (POST, 2006). However, numerical argument has proven inadequate to the task of convincing the public, and in particular those non-governmental groups who lead opinion, that nuclear powered electricity generation is a tolerable risk. The result has been that political and legal opposition has thwarted nuclear programme plans in the UK for some time.

As a concept, trust deficit may also be expanded to include the relations between industry and the government. Venture capital for new-build energy plant is unlikely to be forthcoming if changes to regulatory standards cannot be predicted with any certainty during the initial investment period. The application of safety regulations, and the timescale of the regulatory process, have potential impacts to the regulated population that may be equally severe as the imposition of imprecise or excessively demanding engineering standards. Regulatory actors cannot therefore discharge their duty by simply determining some compromise level of tolerable risk that balances diverse numerical risk levels.

Given the need to reflect the broad range of societal risk tolerance levels in the regulation of civil nuclear power, and the failure in matching diverse tolerance standards by redressing the “information gap” in a process of education, the apparent shortfall in trust and its influence on the perceptions and motivation of different stakeholders would appear to be a way ahead. In establishing or preserving trust, a pivotal factor is justice.

4. The trust gap and justice

If we take trust to be confidence in a quality of some person or other stakeholder, then in risk management that confidence needs to be in their just behaviour if trust is to be established or preserved. To retain legitimacy, any government, and its servants, must act with justice. In this context it is worth noting Adam Smith’s second duty of sovereigns, which is “protecting, as far as possible, every member of the society from the injustice or oppression of every other member of it" (Smith, 1776), which neatly intertwines the duties of risk management and justice in governance.

In the case of the regulation of bulk energy production, whether the information deficit model is representative or not appears to be irrelevant, as there can be no sound basis for risk governance without exemplary justice – particularly when dread risks are involved. Regulatory actors may pride themselves in being above politics and necessarily divorced from their political masters, yet regulators' legitimacy stems not only from their appointment but also their behaviour. In order to retain legitimacy and credibility, their decisions must not only reflect the risk tolerance of the community they serve, but earn and retain its trust by embodying popular conceptions of justice. Without legitimacy, the right of regulatory actors to exercise legal sanction is theoretical at best. By the exercise of exemplary justice within the discretionary boundaries of legal constraints, regulatory actors have the opportunity to maintain the essential contract of trust between government and the governed. If regulation is perceived to fail in being conducted with justice and thereby loses popular trust, members of the community may seek other means of mitigating their risk. For example, they may turn to direct action to impede operations they regard as hazardous.

Although the concept of justice has been approached from a number of perspectives, within this paper it will be regarded as having two related elements – distributive and retributive. In this regard, the argument follows the distinction identified by Campbell (1988), following Aristotle, between distributive justice and commutative justice. Aspects of restorative justice are subsumed within the retributive domain.

In respect of the provision of bulk electrical power, the distributive aspects of justice have to do with ensuring that not only are the benefits of electricity equally apportioned, but also the risks associated with its generation. The retributive aspect has to do with providing an assurance that where harms have been visited on human beings or the environment as the result of malfaisant, negligent or reckless decisions in power generation, those responsible will be held to account. Both aspects of justice are involved in the proper governance of environmental risk in society, and both are likely to influence risk tolerance.

5. Distributive justice and environmental risk

Whatever the mathematical niceties of risk measurement and comparison, risk tolerability is critically influenced by a number of factors that are more readily addressed by negotiation than calculation. The process of risk apportionment has complex effects in relation to risk tolerability. In particular, the degree of dread and the imposition of a risk are factors that are likely to attract lower societal risk tolerance levels and demands for greater commensurate scrutiny from regulators. As Focht and Trachtenberg (2005) note, individuals are more content to leave their interests in the hands of policy officials when they feel that those interests are being properly represented. If some stakeholders do not believe that regulators are taking the care they feel necessary, then those who feel endangered will seek closer participation (*ibid.*) in the decision process. Their level of engagement may extent to adopting alternative strategies to protect themselves. Where stakeholders' frames of reference are conditioned by comparisons between how they are treated and the treatment of others, a regulatory system that distributes risks and benefits in a broadly equivalent and just manner, is more likely to encourage citizens to trust their interests to the hands of government.

Clearly, this decision applies at multiple levels. At the level of strategic choice, the Government needs to determine as a matter of policy whether a new build nuclear power programme will be the means of addressing the forthcoming power supply shortfall. The current consultation process (DTI, 2007 a, 2007 b) is an aspect of informing that choice and balancing the inherent benefits and risks for the population as a whole. At the level of policy implementation, which is the level of interest to the regulators, the choices concern reactor design approval, site selection and the audit of plant operations.

However, what is to be the yardstick of this equable distribution? There is an inherent difficulty in attempting to render the exercise one of engineering. Starr's 1969 findings determined the general disparity between the tolerability levels of voluntary and involuntary risk as some three orders of magnitude. That is, in general the public will tolerate probability levels for imposed risks that are a thousand times lower than those that are voluntarily assumed. Starr's findings readily explain that which governments find frustrating and incomprehensible; people will happily smoke, and drive while not wearing their seatbelts because they are voluntarily undertaking activities from which they derive immediate benefit. By contrast, they may well be affronted by the imposition of a power station in their locality with a vanishingly small likelihood of a catastrophic accident.

This leaves the regulator as an adherent of scientific principles with a significant challenge. Subtracting three orders of magnitude from a starting point risk level equivalent to the maximum permissible occupational exposure for an industrial worker, the numbers rapidly descend to the point where they verge on the empirically unverifiable. The maximum permissible occupational risk exposure for an industrial worker in the United Kingdom is 10^{-3} per annum (HSE, 1988 revised 1992). That is, one chance in a thousand during a period of one year that an individual will suffer a fatal injury of any sort as a direct result of their employment. Of course, reducing such a level by three orders of magnitude to one chance in a million (10^{-6}) of suffering a fatal injury during a one year period does not mean that 10^{-6} is a mathematically meaningless concept. However, very small probability numbers may defy the potential for refutation if experiments to test numerical assertions are of unrealistic duration; and if an assertion may not be tested, at least in principle, it cannot claim a sound scientific basis [vi].

In practice, maximum tolerable public exposure levels are mandated by government on the basis of scientific guidance, and in the United Kingdom the HSE promulgates a bench mark level for new nuclear power stations of 10^{-5} per annum for an individual member of the public (HSE, 1988 revised 1992), a figure derived from Barnes' (1990) report on the Hinkley Point 'C' enquiry. Although the HSE (1988 revised 1992) reasoning induced that for any industry the upper maximum occupational exposure was 10^{-3} per annum, and the maximum for any member of the public could be no higher than an order of magnitude less (10^{-4}), they conceded Barnes' (1990) proposal of 10^{-5}. An annual risk of 10^{-5} is just short of three orders of magnitude lower than the average figure for death by cancer (HSE, 1988 revised 1992 and sources therein), and therefore roughly accords with Starr's (1969) observation regarding involuntary risk, and also his finding that the public tend to measure risk by comparison with death by natural causes. However, while application of the ALARP (As Low As Reasonably Practicable) principle may reduce the actual exposure of members of the public to 10^{-6} or less (HSE, 1988 revised 1992), proving that such levels have been achieved is another matter.

Attempts are made by a number of countries to incorporate risk aversion directly into regulatory practice by the inclusion of differential risk aversion (DRA) factors into risk tolerability calculations using various formulae (Nordland, 1999). These account for factors such as dread, and lack of victim control of a process, and adjust risk tolerability in inverse proportion to casualty numbers using a linear or exponential function (*ibid.*). However, applying a term for dread into an equation to reduce numerical risk exposure does not necessarily incorporate the complexity of factors that condition risk tolerance. In particular, it neglects the critical relationship between risk and benefit, detailed consideration of which stakeholders are to receive which risks and which benefits, and above all, for how long.

Two further aspects that impede the treatment of this problem as an exercise in mathematics reside in the human realm. Serious accidents, that is, those that result in permanently disabling or fatal injury, and catastrophic accidents, which are those resulting in a hundred fatalities or more in a single event, may evidence poor, reckless, or negligent human behaviour (Perrow, 1999). However, as Charles Perrow (1999) notes, catastrophes are rare events not because human beings make infrequent errors, but because the eventuation of a catastrophe often requires the combination of a number of factors. Such a combination determines the number of unprotected individuals who will be enveloped by an efflux cloud from an industrial site while it is still in toxic concentration. In the case of an industrial accident, the circumstances critically effecting casualty numbers may include wind speed and direction, since these determine the drift of toxic clouds; warning system failure, the proximity of mass human habitation, and the time of the accident, because the location of potential casualties changes during the course of a given day (*ibid.*). Since the coincidence of accidents and the combinations of factors that engender numerous casualties occurs rarely, the population is shielded from multiple fatalities not so much by the mathematics of sound engineering, but by the mathematics of chance events (*ibid.*). Human beings managing potentially harmful processes may fail frequently, but for their failures to prove catastrophic rather than fatal for a few individuals, those failures have to be accompanied by a rare set of conditions (*ibid.*). This is disconcerting, given the relatively modest understanding of human error as a set of probabilistic functions.

The second factor that tends to defeat the mathematical treatment of risk where human beings are involved concerns malicious behaviour. One of the key objections to nuclear newbuild concerns the potential for such plant to become the focus of terrorist attack (Greenpeace, 2006). Safety analyses for nuclear installations have been undertaken, but insufficient information exists from which to draw firm conclusions on the likelihood and outcomes of such an attack (POST, 2004). The problem is a familiar aspect of defence policy; it cannot be known with certainty who the enemies of the future will be and this complicates planning. The British were taken by surprise by the Falklands invasion of 1982, despite the intelligence indications that were available. The probabilities of attacks on installations fluctuate with the political tides, and the best that can be done is to either eliminate hazards or concentrate on mitigating impacts.

6. Time as a measure of risk

Since mathematical approaches to risk management and regulation have significant inherent flaws, the options are to either continue with current regulatory strategies or pursue new approaches. We can accept our present system as imperfect but not worth altering, perhaps in the hope that the lessons of the past have all been some historical aberration, or because we fear regulatory innovation. Alternatively, society may seek to improve and develop its regulatory methods and perhaps gain regulatory efficiency and decision quality.

For a regulatory system to be run with exemplary justice there will need to be some system of measurement, even if the engineering mathematics is not compelling. There will need to be some yardstick of distribution or basis by which the apportionment of risks and benefits can be compared. Perhaps the most just measure for such risk distribution is time. The duration of exposure of a risk or the duration of a benefit is a factor that has long been considered in determining equality. Kenneth Arrow, whose celebrated work on the impossibility of aggregating individual preferences into societal choices earned him an enduring place in economics, alludes to the use of time as a measure of distribution in relation to the human life span (Arrow, 1951). A modern implementation of such an idea is the Quality Adjusted Life Year or QALY, which has been used within the UK health service as a means of determining the potential benefit that given expenditures may bring to a specific cohort of the patient population (Phillips and Thompson, 2001).

The QALY system assumes that a year lived in perfect health has a value of one (Phillips and Thompson, 2001). A set of parameters such as the degree of mobility an individual has, or the degree of pain they endure on a daily basis degrades that figure, and by multiplying the "quality adjusted" number for one year by the number of years a patient is expected to survive, a number of full value equivalent years can be derived (*ibid.*). The anticipated benefit of an intervention may raise the quality value of each year, increase the number of years remaining to a patient, or both (*ibid.*). By this means, the cost-benefit of treatments for entirely different cases can be assessed with some equity (*ibid.*). Although subjective (*ibid.*), the system is relatively simple.

A similar approach to cost-benefit is taken by Thomas, Stupples and Alghaffar (2006 a, 2006 b) using a technique founded on 'J-values', where J refers to 'judgement'. A J-value is a mathematical correlation of average life expectancy, average income, and fraction of time spent in work, against expenditure on safety investments (Thomas et al., 2006 a, 2006 b). Although recommended by its authors as a common yardstick for the measurement of proposed safety expenditure across different sectors, J-value analysis rests on a number of assumptions[vii] (Thomas et al., 2006 a, 2006 b). However, it does emphasise the significance of time in the evaluation of risk to a given population (Thomas et al., 2006 a, 2006 b).

Using time as a yardstick in the distribution of benefit and risk enables the duration of those outcomes to be compared on a more readily measured basis. This has a particular relevance when comparing the apportionment between different stakeholder groups. Perhaps more important, it renders obvious one of the most striking issues in decision-making for major projects associated with social welfare, and that is the very different time horizons and time pressures the different stakeholders may have. Bulk energy production is a typical example of such a problem.

The application of such a system involves a searching and transparent attribution of benefits and risks to determine for any given generation plant; "qui bono?" Commentators such as Nordland (1999) have proposed equations that attempt to relate risk tolerability to benefit, and incorporate some aspects of time into the algebra. However, what is proposed here, although by no means a simple task, is the identification of the various risks and benefits for *each* major stakeholder group associated with a prospective power installation, to ensure both that the tyranny of the majority does not operate without some reasonable compensation, and that long term projects are planned from the onset in their entirety, despite political expediency and market imperatives. Such a process might include the use of a form of bar chart to ease the comparison of risk *and* benefit for each stakeholder, identifying the magnitude of risk and benefit against their respective *durations* (Ash, 2007). The disparate time horizons of stakeholders may have significant influence on their risk tolerability (*ibid.*).

[Figure 2 here]

Figure 2 depicts a specimen bar chart for a prospective power generation plant. The symbols are chosen to ensure that risks and benefits are represented both in intensity *and* duration. Risks may be to life or financial, and while in this diagram they are combined, it is not essential and has been done to simplify the image. It will be noted in this case that the majority of the risk to the commercial stakeholders resides in the development phase of the project; uncertainty regarding design changes mandated by regulation. The regulatory stakeholder risk consists to a great extent in occupational exposures to personnel during audit and enforcement activities. The government gains tax revenues during the operation of the plant, but both commercial and government stakeholders are liable for costs resulting from accidents and decommissioning. Local inhabitants and the general public are subject to risk exposure for extended periods of time. An arguable benefit may be had by local inhabitants in employment, and by the general public in the availability of power. The NGO cohort is by no means monolithic in its views and is taken here to be those organisations resisting the project. They are at risk when campaigning against the project as they may lose the opportunity cost of their involvement, but may potentially gain some income from publicity during the project's life. Such a diagram is a potential vehicle for the public consideration of *relative* risks and benefits. Thus, the details of the depiction would be debated with the merits of each prospective project.

The failure in the past to consider in an explicit and transparent manner the recipients of potential risk and benefit has characterised bulk energy supply in the United Kingdom. Regulatory myopia is becoming increasing difficult to practice, but a process of risk allocation that is both transparent and explicitly time-sensitive may avert the administrative stalemate that has characterised the UK nuclear programme, and spectacles such as the recent defeat of the DTI's energy paper consultation in the High Court by Greenpeace (Greenpeace –v- Secretary of State for Trade and Industry, 2007) (CORWM, 2006). In contentious issues, decision-making benefits from openness, and much has been achieved by the deliberative approach adopted by the Committee on Radioactive Waste Management (CORWM). Interestingly, one of the key elements that drove CORWM's recommendation for long term waste disposal was the risk of losing institutional control (CORWM, 2006); empires tend to endure for centuries, but some radioactive emitters have half-lives measured in millennia. CORWM's decision process and concern with risk management over long periods has an interesting parallel in the proposals of Thomas Sebeok (1984). Sebeok was engaged to examine means of alerting future generations that radioactive waste repositories would be hazardous to interfere with (*ibid*). Concluding that no infallible means of communication would survive the 10,000 year period needed to accommodate radionuclide half-lives, Sebeok proposed that an 'atomic priesthood' could be established to periodically re-encode the warnings (*ibid*).

7. The role of retributive justice in building trust

The retributive aspect of justice is one that has always been contentious. It may be argued that punishment acts as a deterrent and brings an increased likelihood of conformity with desired behaviour, but societal aims in this case have more to do with the elimination of negligent or reckless behaviour than with the malicious. Moreover, considering Perrow's arguments, for some processes, no amount of deterrence may avert catastrophe, and the best that can be done is to avoid certain activities altogether (Perrow, 1984 reprinted 1999). In the domain of the regulation of bulk civil energy supply which is the context of this paper, it is of note that Perrow identifies nuclear power as an activity to be avoided (*ibid.*). His argument concludes that certain activities are in critical respects ungovernable as no group of managers or system operators can be expected to keep them permanently under the necessary control (*ibid.*) [viii]. The logical extension of this view is that for some bulk energy supply processes, specifically nuclear generation, no regulatory system will bring acceptable risk governance. Moreover, believing thoroughness and care to be no safeguard against catastrophe and blame, it is likely that in the face of an aggressive regulatory strategy, senior managers will simply avoid particular process areas and sites – perhaps those most in need of professional management. Thus, deterrence may have the effect of conditioning a societal benefit in that ungovernably risky processes are shunned for want of management, but by the same token, too aggressive a system of regulation may inhibit the recruitment of capable managers for the unavoidable task of addressing legacy waste and site contamination.

The riposte to Perrow's argument was led by Karl Weick (1987), who was curious to determine why complex activities with tightly bound process elements and potentially catastrophic outcomes did not in practice seem to eventuate as predictably as Perrow's work would seem to suggest. Perrow's thesis holds that human activities can be categorised along two axes; complexity, and the degree to which process stages are tightly coupled (Perrow, 1984 reprinted 1999). A process is complex if it consists of many elements or its components are related in a recursive fashion (*ibid.*). Its components are tightly coupled (connected) if they are in close physical proximity or the activation or product of one stage inevitably or rapidly impinges on the next component (*ibid.*). The best, and in some cases the only, management tactic for addressing complexity is to delegate or decentralise the management function (*ibid.*). By contrast, the tactic for best managing a tightly bound process is to centralise, as their control is often time-critical (*ibid.*). Clearly, if a process is *both* complex and tightly bound its management becomes problematic as its best governance requires both centralisation and decentralisation (*ibid.*). Weick (1987) opines that some organisations can indeed do both, creating a highly reliable culture by a process in which central management inculcates into staff a set of rules determining when they may act on their own, and also specific cues to react to in analysing given situations. This therefore enables delegation to occur with rapidity in the face of complex and hazardous situations, but with judgements closely aligned with the preferences of central management (*ibid.*).

Although by no means conclusive, Weick's position is interesting because it emphasises the internal governance of potentially hazardous processes. That is, the behaviours of those managing and undertaking an activity are limited by a system of education and professional interaction that takes place largely within an organisation or industry. The regulation of industrial processes such as bulk power generation may in general be regarded as largely internal or at least extra-governmental, since the majority of the on job training, continuation training, professional standard setting and procedure writing is conducted by practitioners as opposed to government personnel. However, Weick (1987) notes that the driving force in high reliability cultures is the personnel in the centre of organisations. It is they, rather than specialist government appointed external scrutinisers that are largely responsible for a lack of accidents in the complex, tightly connected and potentially catastrophic activities they manage. Thus, the process of creating regulations and good practice standards requires collaboration between regulators and the regulated if is to be successful, and a system that entirely depended on external regulation for industrial practices would require the transfer of enormous expertise and cost to the public sector in order to function effectively.

The key to obtaining justice in a system of regulation therefore is not simply to impose crushing penalties in the expectation that it will bring about deterrence. Indeed, it may be that such a system is innately unjust to those who venture much needed capital or exercise scarce skills in the provision of services important to society as a whole. Moreover, if an aggressive regulatory system is imposed thoughtlessly on aspects of UK bulk energy production, the unintended consequence is likely to be the abandonment of that commercial sector by investors and managers. This in turn will almost certainly bring about an increasing reliance on externally sourced fossil fuels; a risk the government evidently considers most undesirable (DTI, 2007 a). It may also encourage secrecy in industry and practices such as the falsification of documents [ix]. A closed or opaque system is not likely to be one that learns from errors and consequently takes preventive measures.

Personal accountability, as opposed to mere draconian deterrence, is certainly a powerful spur to conformity (Forlin, 2001). In particular, where it is applied to the centre of organisations - the focus of the controlling mind – then if Weick’s model is correct, it is applied at the most effective point. Safety is everyone’s concern, but if a safety culture grows under the directing hand of those at the centre, then it is at that centre that deterrence will likely have the most effect.

Personal liability at the centre has in the past proven remarkably challenging to achieve in cases in which fatal accidents have occurred. This is not to assert that the United Kingdom Health and Safety Executive (HSE) does not bring prosecutions or achieve convictions for workplace accidents. Yet in cases in which members of the public have been victims of fatal events in which there were clear shortfalls in good and acceptable practice, the bereaved may be mystified by a legal system that has no explicit corporate killing legislation, that has difficultly in establishing clear links to the directing mind of an organisation, and that deals imperfectly with matters of negligence [x]. Moreover, they will likely regard handsome bonus payments to board members following major accidents as an affront to natural justice, and doubtless dismiss any argument that such payments are calculated only in part on HSE performance as a pettifogging ruse to evade clear moral responsibility.

How can such a situation be redressed? The main provisions of the Corporate Manslaughter and Corporate Homicide Act 2007 come into effect on 6 April 2008 (MJ, 2007). It does not introduce prosecution against specific individuals (*ibid.*), and therefore does not bring the level of accountability that some had hoped for[xi]. However, the law as it currently exists might still be used to place a careful thumb on, and thereby level, the scales of justice – a practice referred to by Andrew Dunsire (1993) as “collibration”, and a powerful regulatory tactic.

The focus should be on dread fears rather than statistical fatalities. That is, those perils arising from bulk power supply that are potentially catastrophic, delayed in eventuation, invoke feelings of particular fear, are inequitably distributed or arise from involuntary processes. Since the criminal law does not invoke sufficient confidence in the public that it fully represents their interests, the alternative is to look to the civil law and contracts. It is proposed that directors of power utilities be encouraged to enter into personal liability agreements, subject to the disposal of independent third parties under the civil procedures rules of 1999 (OGC, 2002) [xii], to provide some assurance that the bulk of any compensation is not absorbed in legal fees. Where necessary, the investigation of incidents may be undertaken by independent persons, agreed in advance under the terms of the liability contract between board members and other stakeholders. The proposal is in effect an adjunct to existing regulation, establishing collateral against just performance; a test of good faith by the commercial undertaker. The method is a simple one – all board members equally and individually commit to a liability agreement under which, irrespective of any calculation made by the company, they will forfeit the entirety of their bonus or a significant proportion of their salary for any year in which a serious accident occurs as the result of a management failure. The company, having a legal personality of its own, will similarly commit not to retain those monies for its own purposes. Instead, they will be used either for the medical costs of casualties or environmental remediation. Unlike fines in criminal cases, monies will not pass to the Treasury.

The term ‘management failure’ is significant. As a basic requirement, it is taken here to include the following:

- Tolerating the absence of an audited safety plan that embodies good standards.
- Failing to check periodically and frequently that employees are implementing the plan.
- Deliberately diverting or withholding resources from safety and environmental procedures such that the safety plan is compromised.
- Failing to ensure a transparent and auditable safety process.

These requirements may at first appear elementary. They also do not conform to the current practice within the HSE of requiring risks to be managed to a level As Low As Reasonably Practicable (ALARP). However, the history of catastrophic accidents reveals a distressing frequency of incidents in which basic good practice was not followed. Moreover, if an auditable safety plan cannot be devised that ensures the moderation of risks to tolerable levels, then the subject activity should not be licensed. For example, Perrow (1999) notes the accident at the Union Carbide plant at Institute, West Virginia. This event occurred on 11 August 1985, 8 months after the catastrophic release of Methyl Isocyanate in 1984 from the company’s site at Bhopal, and after an OSHA inspection had raised no significant observations (Perrow, 1999). For the audit to have failed to detect the shortcomings that led to the release at the Institute plant, either the audit procedures were at fault, or the plan was, or the plan was inappropriately followed after the inspection date. In any event, public trust in the regulation of complex and hazardous industrial processes will only be created and preserved if it is demonstrated that a safe system of operation is both possible and adhered to. It is for the regulators to determine whether a process can be bought under systemic control, and such control includes the capacity of the system to be audited and described as a set of basic procedures. It is for retributive processes to address process accidents that occur as the result of a failure to follow clearly defined procedures.

Of course, if board members are not sufficiently confident of the safety of their plant design or operation to make such a personal commitment, it must be asked why members of the public should be exposed to the risks posed by the subject installation. It is after all a fact of commercial life that society rewards risk takers. One of the most spectacular exemplars of this is Elisha Graves Otis. Otis demonstrated his patent safety elevator at the World's Fair of 1854 by the simple expedient of standing on the travelling platform while the rope that suspended it was severed (Otis a, 2007; Otis b, 2007). When the safety mechanism arrested the fall he is reported to have cried to the crowd of onlookers "all safe, gentlemen!" (Otis b, 2007). Today, the company that bears his name is the largest in the manufacture, maintenance and installation of vertical transportation systems (Otis b, 2007).

Sandman (1993) views accountability as a proxy for trust, and views negotiated contracts as the ultimate in accountability. However, while contracting personal liability may invoke public confidence in a process or installation, there are other potential benefits to the practice that are worthy of note. A commitment to personal liability draws the focus of safety oversight back to internal regulation. While it is neither practical nor desirable to abandon external regulation entirely, the control of safety by practitioners is control by those who both know the workplace best and stand closest to its potential hazards. Internal regulation tends also to be more efficient. If process managers have sufficient confidence and responsibility to assume personal liability, then regulatory agencies should use the discretion the law allows them to effect a compensating moderation of the administrative burden they impose on industry. This in turn permits a saving on the cost of regulation to the public purse.

Contractual liability as an inducement to good safety performance will certainly require some oversight by regulators, but by a process of building public trust, should enable less focus to be placed on numerical methods, which neither convince the public nor are usefully applied to issues such as deliberate attacks on power stations. Care will be needed to ensure that in the case of overseas based or multinational companies, contracts will be binding. External regulatory oversight will also be needed to protect managers from their own unreasonable beliefs in respect of safety. That is, to prevent them from tolerating risks that are unrelated to the real world and entering into agreements that leave them unjustly exposed. A clear example of this can be discovered in the Challenger launch decision (Feynman, Undated). As part of his work in respect of the Challenger loss, Richard Feynman identified that estimates of launch to failure were judged ranging from some 10^{-2} to 10^{-5} (*ibid.*). The curious part was that the working engineers gave the more pessimistic and representative answer (*ibid.*). Managers apparently either believed that it was possible to launch a shuttle a day for 2 ¾ centuries and that only one would explode, or did not relate the number to the concept. Numbers are not sufficient for regulation, but they are necessary in managing risk.

8. Conclusions

Regulatory practice rests on satisfying a triad of factors: the risk tolerance of the community that is served, the methodology that is used to measure and enforce tolerable risk levels, and the resources available to the regulatory agency. In practice, these factors are likely to be interdependent, rather than elements in a linear process that first establishes a societal risk tolerability level, then identifies an appropriate regulatory methodology, and finally seeks the necessary funding.

Obtaining satisfactory solutions for the triad can be defeated if any one of the factors is set at a level incompatible with the others, or is unreflective of societal reality. This has happened in issues related to bulk civil power generation, and in particular, issues related to addressing the anticipated shortfall in UK supply with new nuclear plant. For some members of society, risk levels associated with this technology are too high for it to be entertained. However, setting regulatory risk tolerability levels that are too exacting or worse still, fluctuate in application, may not only dissuade capital investment, but needlessly waste resources. Noting the failure of the “knowledge gap” approach to allaying public fears concerning nuclear bulk power generation, this paper outlines a regulatory strategy based on upholding standards of justice. The concept is for regulatory bodies to uphold exemplary standards of justice and thereby re-establish public trust.

Justice may be considered essentially as two complimentary elements; the distributive and the retributive. This paper addresses both elements in proposing measures to satisfy a social welfare requirement – the provision of sufficient bulk electricity – without affronting natural justice in the treatment of specific stakeholders or individuals. The distribution of risks and benefits in society from nuclear generation is rendered more explicitly just by the use of time as a metric for fair comparison. The need for deterrence from unacceptably poor risk management is addressed by the use of civil contracts to ensure compensation in the event of serious accidents and the curbing of financial gain despite inadequate managerial performance. Although it favours neither nuclear nor non-nuclear approaches to electricity generation, the argument strongly supports just and transparent regulatory practice for all sources of bulk civil power.

Acknowledgements

This work was funded by the United Kingdom Economic and Social Research Council within the purview of their ‘Towards a Sustainable Energy Economy’ programme. The author gratefully acknowledges the observations and suggestions provided by colleagues in the Electricity Policy Research Group at the University of Cambridge. The author also acknowledges the comments received when an initial form of the paper was presented at the second Annual Cambridge Conference on Regulation, Inspection and Improvement, held at Peterhouse College, University of Cambridge on 12 September 2007.

References

ANAB (2007) *Nuclear Power, Climate Policy and Sustainability: An Assessment by the Austrian Nuclear Advisory Board*. Austrian Nuclear Advisory Board, Vienna, AV + Astoria Druckzentrum GmbH.

http://www.nirs.org/climate/background/austriangovtreport607.pdf accessed 14 November 2007.

Arrow K (1951) *Social Choice and Individual Values.* John Wiley & Sons Inc., New York.

Ash J (2007) *The Management of Anthropogenic Environmental Risk Associated With Oil Development in the Arctic Littoral.* Unpublished PhD thesis, University of Cambridge.

Bardach E, Kagan RA (1982) *Going by the Book: the Problem of Unreasonableness*. Temple University Press, Philidelphia. Cited in Dunsire, 1993.

Barnes M (1990) *The Hinkley Point Public Enquiries: A Report by Michael Barnes QC*. HMSO.

BE (2007) *About British Energy*. British Energy. http://www.british-energy.com/pagetemplate.php?pid=77 Accessed 28 February 2008.

Burgess J, Harrison C, Filius P (1998) Environmental Communication and the Cultural Politics of Environmental Citizenship. *Environment and Planning A* 30(1), 1445-1460. Cited in Owens and Driffill, 2006.

Campbell T (1988) *Justice*. MacMillan Education Ltd., Basingstoke.

Cohn SM (1997) *Too Cheap to Meter: An Economic and Philosophical Analysis of the Nuclear Dream*. State University of New York Press, Albany.

CoRWM (2006) *Managing our Radioactive Waste Safely: CoRWM's Recommendations to Government*. CoRWM Doc 700. Committee on Radioactive Waste Management, July 2006.

Dickson AF (1971) *Navigation Problems (Tankers)*. International Tanker Safety Conference. International Chamber of Shipping, London. Cited in Perrow, 1999.

Dobson A (1998) *Justice and the Environment: Conceptions of Environmental Sustainability and Dimensions of Social Justice*. Clarendon, Oxford.

DTI (2007 a) *Meeting the Energy Challenge: A White Paper on Energy*. CM 7124, Department of Trade and Industry. The Stationery Office.

DTI (2007 b) *The Future of Nuclear Power: The Role of Nuclear Power in a Low Carbon UK Economy: Consultation Document*. DTI/Pub 8577/2.5k/07/07/RP.URN 07/970. Department of Trade and Industry.

Dunsire A (1993) *Manipulating Social Tensions: Collibration as an Alternative mode of Government Intervention*. MPIFG Discussion Paper 93/7. Max-Planck-Institut für Gesellschaftsforschung, Köln.

EA (2004) *Guidance for the Environment Agencies' Assessment of Best Practicable Environmental Option Studies at Nuclear Sites.* Document developed by the Environment Agency (EA), the Scottish Environment Protection Agency (SEPA). February 2004.
http://publications.environment-agency.gov.uk/pdf/PMHO0204BKHK-e-e.pdf
accessed 26-28 February 2008.

Eden S (1996) Public Participation in Environmental policy: Considering Scientific, Counter-Scientific and Non-Scientific Contributions. *Public Understanding of Science* 5, 183-203. Cited in Owens and Driffill, 2006.

Feynman RP (Undated) *Appendix to the Rogers Commission Report on the Space Shuttle Challenger Accident*. http://www.ralentz.com/old/space/feynman-report.html

Focht W, Trachtenberg Z (2005) A Trust-Based Guide to Stakeholder Participation. In: Sabatier P, Focht W, Lubell M, Trachtenberg Z, Vedlitz A, Matlock M (eds.) *Swimming Upstream: Collaborative Approaches to Watershed Management*, pp. 85-135. MIT Press, Cambridge Mass.

Forlin G (2001) *Corporate Killing and Health and Safety: Where are we Now?* London Chamber of Commerce and Industry Conference on Accidents. http://www.rospa.com/occupationalsafety/info/corporate_killing_forlin.pdf
accessed 13 June 2007

Fremlin JH (1989) *Power production: what are the risks*? Adam Hilger, Bristol. 2nd ed.

Furedi F (1997) *Culture of Fear: Risk-taking and the Morality of Low Expectation*. Cassell, London.

Greenpeace (2006) *Nuclear Power and Terrorism*. Greenpeace media briefing dated January 2006.
http://www.greenpeace.org.uk/files/pdfs/migrated/MultimediaFiles/Live/FullReport/7357.pdf accessed 23 October 2007.

Hawkins K (ed.) (1992) *The Uses of Discretion*. Clarendon, Oxford. [1994 imprint].

HSE (1988) *The Tolerability of Risk from Nuclear Power Stations*. Health and Safety Executive. HMSO, London. Revised 1992.

HSE (2006) *Safety Assessment Principles for Nuclear Facilities*. Health and Safety Executive, Bootle.

HSE (2007) *Nuclear Directorate – Who We Are*. 5 November 2007. http://www.hse.gov.uk/nuclear/nsd1.htm#staff Accessed 28 February 2008.

HSE, EA, SEPA and OCNS (2007) *Guide to Regulatory Processes for Generic Design Assessment of New Nuclear Power Stations*. The Health and Safety Executive (HSE) with the Environment Agency (EA), the Scottish Environment Protection Agency (SEPA) and the Office for Civil Nuclear Security (OCNS). Version 1, January 2007. http://www.hse.gov.uk/nuclear/reactors/toptier.pdf accessed 5 November 2007.

McKee K (2006) *Alternative Dispute Resolution*. Alway Associates. http://www.alway-associates.co.uk/alternative-dispute-resolution.asp accessed 14 June 2007 and thereafter.

McKenzie-Mohr D (2000) Promoting Sustainable Behaviour: An Introduction to Community-Based Social Marketing. *Journal of social Issues*, 56 (3), 543-554. Cited in Owens and Driffill, 2006.

MJ (2007) *A Guide to The Corporate Manslaughter and Corporate Homicide Act 2007.* Ministry of Justice, October 2007.

Monbiot G (2005) *The Business of Killing*. The Guardian, 27 April 2005.

NII (2000). *An Investigation into the Falsification of Pellet Diameter Data in the MOX Demonstration Facility at the BNFL Sellafield site and the effect of this on the Safety of MOX Fuel in Use*. HM Nuclear Installations Inspectorate, 18 February 2000.
http://www.hse.gov.uk/nuclear/mox/mox1.htm#FOREWORD and associated pages.
Accessed 14 November 2007.

Nordland O (1999) A Discussion of Risk Tolerance Principles. *Safety Systems*, 8 (3), 1-4.

OGC (2002) *Dispute Resolution Guidance*. Office of Government Commerce. http://www.ogc.gov.uk/documents/cp0077.pdf accessed 24 October 2007.

Otis a (2007). Otis, Elisha Graves In *Encyclopædia Britannica.* http://www.britannica.com/eb/article-9057648 accessed 26 October 2007.

Otis b (2007). [website of the Otis Elevator Company]. http://www.otis.com/otis/1,1352,CLI1_RES1,00.html accessed 26 October 2007.

Owens S, Driffill L (2006) *How to Change Attitudes and Behaviours in the Context of Energy*. Version 1.0. Office of Science and Innovation. http://www.foresight.gov.uk/Energy/Reports/Mini_Energy_Reports/PDF/How_to_change_attitudes_and_behaviours.pdf

Palmer A (1996) *The Limits of Reliability Theory and the Reliability of Limit State Theory as Applied to Pipelines*. OTC 8218. Paper prepared for presentation at the Offshore Technology Conference, Houston, 6-9 May 1996.

Perrow C (1984) *Normal Accidents: Living with High Risk Technologies*. Basic Books, New York. Reprinted 1999, Princeton University Press, Princeton.

Phillips C, Thompson G (2001) *What is a QALY?* ONC 195058.
http://www.jr2.ox.ac.uk/bandolier/painres/download/whatis/QALY.pdf

POST (2004) A*ssessing the Risk of Terrorist attacks on Nuclear Facilities*. Parliamentary Office of Science and Technology report 222, July 2004.

POST (2006) *Carbon Footprint of Electricity Generation*. Parliamentary Office of Science and Technology report 268, October 2006.

POST (2007) *Electricity in the UK*. Parliamentary Office of Science and Technology, report 280, February 2007.

Pritchard P (2000) *Environmental risk Management*. Earthscan, London.

RCEP 1988 *Twelfth Report. Best PracticalEnvironmental Option*. Cm 310. Royal Commission on Environmental Pollution. HMSO, London, February 1988. Cited in EA, 2004.

Sandman P (1993) *Responding to Community Outrage: Strategies for Effective Risk Communication*. American Industrial Hygiene Association press, Fairfax.

Sebeok TA (1984) *Communication Measures to Bridge Ten Millenia*. BMI/ONWI-352. Technical report prepared for the Office of Nuclear Waste Isolation, Columbus.

Smith A (1776) *An Inquiry into the Nature and Causes of the Wealth of Nations*. Methuen and Co. Ltd., London, 1904, 5th Ed.

Smith K (1992) *Environmental Hazards: Assessing Risk and Reducing Disaster.* Routledge, London, 1996, 2nd Ed.

Starr C (1969) Social Benefit Versus Technological Risk: What is our Society Willing to Pay for Safety? *Science,* 165 (3899), 1232-1238. 19 September 1969.

Thomas PJ, Stupples DW, Alghaffar MA (2006 a) The Extent of Regulatory Consensus on Health and Safety Expenditure. Part 1: Development of the J-Value Technique and Evaluation of Regulators' Recommendations. *Process*

Safety and Environmental Protection, 84 (B5), 329-336. Institution of Chemical Engineers. September 2006.

Thomas PJ, Stupples DW, Alghaffar MA (2006 b) The Extent of Regulatory Consensus on Health and Safety Expenditure. Part 2: Applying the J-Value Technique to Case Studies Across Industries. *Process Safety and Environmental Protection*, 84 (B5), 337-343. Institution of Chemical Engineers. September 2006.

Weick KE (1987) Organizational Culture as a Source of High Reliability. *California Management Revue*, 29 (2) 112-127.

Cases cited

Greenpeace v Secretary of State for Trade and Industry [2007] EWHC 311 (Admin) CO/8197/2006.

Laws cited

Corporate Manslaughter and Corporate Homicide Act 2007

Environment Act 1995

Radioactive Substances Act 1993

Figure Legends

Legend for Figure 2:

Where:

———	low intensity risk	- - - - - - -	small benefit
———	medium intensity risk	– – – –	medium benefit
———	high intensity risk	— — —	high benefit

Figures

Figure 1: The Energy Regulatory Triangle

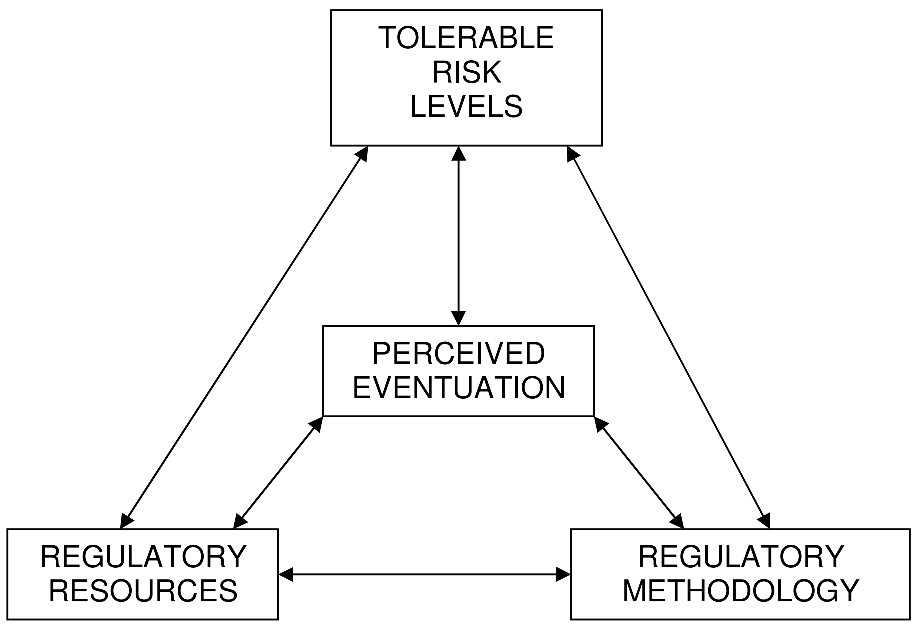
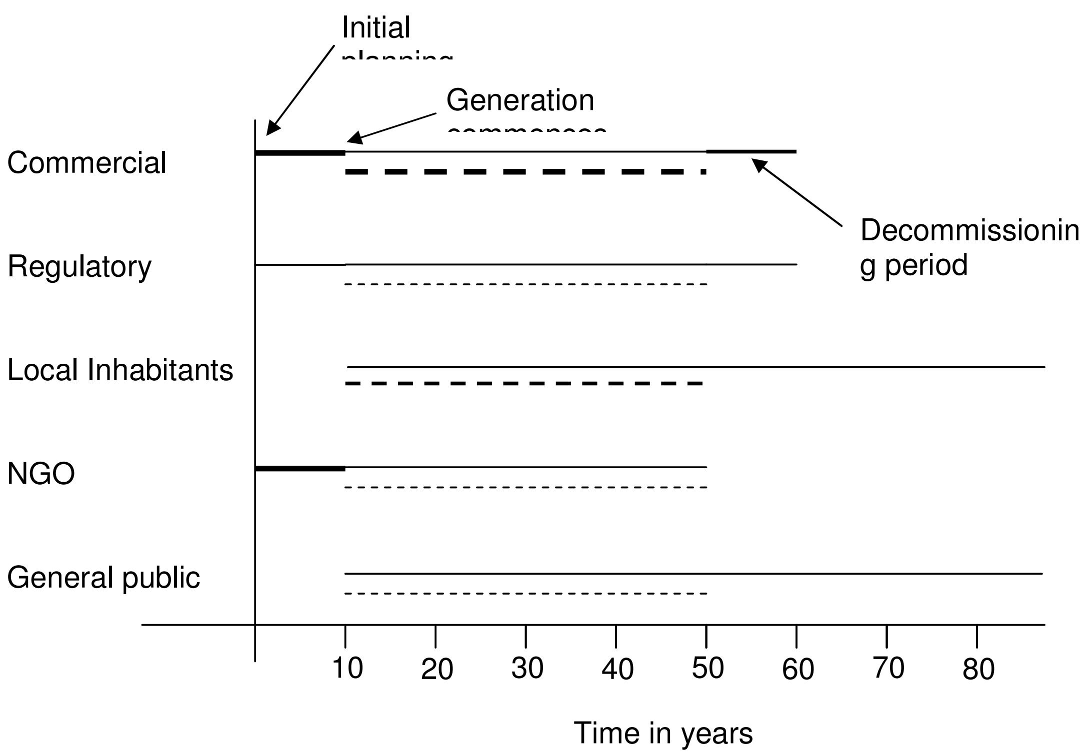


Figure 2: Specimen Energy Plant Risk Comparison Chart



Endnotes

---

[i] This description of the process is a simplification of that currently adopted by the UK Government, under which generic plant design acceptance and site licensing are separate functions that may to some extent be undertaken simultaneously to reduce the duration of the overall administrative process. For a detailed overview of the process see HSE et al. (2007).

[ii] Now the Department for Environment, Food and Rural Affairs (DEFRA).

[iii] Defined by the Royal Commission on Environmental Pollution as a procedure that "…establishes, for a given set of objectives, the option that provides the most benefit or least damage to the environment as a whole, at acceptable cost, in the long term as well as in the short term." (RCEP, 1988.)

[iv] A dread risk is one that invokes particular fear.

[v] Sandman's proposal defies convention, which treats risk as the mathematical product of 'hazard' and likelihood (Pritchard, 2000; Smith, 1992 republished 1996). 'Hazard' is typically glossed as 'A property or situation that in particular circumstances could lead to harm' (Pritchard, 2000). Sandman is therefore using the term 'hazard' to denote what is conventionally thought of as 'risk' in order to include his concept of outrage.

[vi] For a discussion of the validity of very small failure rate predictions in the context of pipeline safety, see Palmer (1996).

[vii] These assumptions include the fraction of a life spent working, which influences life quality index, and discount rate. When applied to problems such as the reduction of radiation exposures to the general public, it assumes the accuracy of the dose response model whose risk factor it incorporates (Thomas et. al., 2006 a).

[viii] Interestingly, this analysis has resonance with a view expressed by some mariners that the International Regulations for Prevention of Collision at Sea (IRPCS) are less a means of ensuring maritime safety than a method of apportioning blame (Dickson, 1971).

[ix] The falsification of records in the nuclear industry has been reported in both the UK and Japan. See for example ANAB (2007) and NII (2000).

[x] Forlin (2001) provides a very interesting overview of corporate killing and criminal liabilities arising from health and safety issues.

[xi] See for example Monbiot (2005).

[xii] See also McKee (2006) for an overview of civil dispute resolution.