SUSTAINABILITY AND ACCEPTANCE — NEW CHALLENGES FOR NUCLEAR ENERGY

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Abstract

This paper discusses the concept of sustainability in relation to acceptance of nuclear energy. Acceptance is viewed in terms of public acceptance, industrial acceptance, and internal acceptance/consensus within the nuclear community. It addresses sustainability criteria, the need for innovation, and the different levels of acceptability. The mechanisms of risk perception are discussed along with the technological consequences from risk perception mechanisms leading to specific objections against nuclear energy.

Summary

Sustainability can be seen as a principle of intergenerational equity and of environmental stewardship with a long-term scope. Due to the danger of an over-stressing of environmental resources by still strongly increasing world population and of the average standards of living, the change towards 'Sustainable Developments' has got the leading political and technological orientation for the 21st century. Criteria for sustainable energy supply systems, however, still have to be defined in a consensual and general way for establishing a guidance to judge the compatibility of different options like nuclear or others.

In the past Climate Protection Conferences nuclear energy has not been considered as a sustainable energy supply option although the nuclear community is strongly advocating with the argument of CO_2-free electricity production. This may be due to the increasing anti-nuclear movements in many countries and the anticipated safety, waste and economic problems.

Sustainability does not only address environmental but also the mental compatibility. The problem of acceptability of nuclear energy and its inter-relationship with technological innovation and evolution of the boundary conditions is discussed on three levels

- public acceptance
- industrial acceptance
- internal acceptance / consensus within the nuclear community.

'Risk Perception' is being understood as a subject / result of complex cultural and social evolution as well as a human sense that does - obviously - not obey to the risk formula being used in nuclear engineering. An attempt is being made to illustrate the mismatch of the two-parameter linear product in the definition of a technical measure for risk and the human sentiment for the acceptance of risk in a multi-parameter interdependence of different additional aspects. A better understanding and 'acceptance' of these mechanisms might lead to an improved communication culture between public, industry and nuclear community.

The socio-political dimension of nuclear energy has to be recognised by the nuclear community by a pro-active attitude in responding to the public awareness for safety and waste issues as well as to the changes in markets and competitiveness also by the development of innovative nuclear technologies as a long-term scope for overcoming these actual problems.

1. Sustainability Criteria

The principle of 'Sustainable Development' can be interpreted as an approach to solve the conflict between ecology, economy and intergenerational social responsibility. This terminology evolved already in the 18th century from forestry that also needs a long-term planning and cultivation. In the 1980th, the concept of 'a development that meets the needs of the present without compromising the ability of future generations to meet their own needs' had been taken up again by the general assembly of the United Nations and in the 'Brundtland Report'. It was also taken as a mayor guideline in the discussions and conferences on climate protection (e.g. Rio, Kyoto) and seems to be a robust and consensual orientation being applied to a broad spectrum of human activities also for the next future [1].

In former times, mankind has always been a 'Solar Community' mainly taking its energy from regenerative sources (e.g. wood, water, wind) and physical labour from humans or animals. This kind of energy supply also created social structures (e.g. bondage, slavery) and hierarchies that have been overcome after entering the 'Fossil Energy Era' about 150 years ago. The impact of using fossil energy on the climate, flora and fauna is obvious and cannot be continued or even enhanced in the long run, thus offering the main argumentation to establish sustainable energy supply structures with reduced emissions of climate gases or toxic substances / wastes endangering present and future generations.

Although nuclear energy is a proven CO_2-free energy supply system it has not been judged as a future tool at the Global Climate Protection Conferences. Recently, the European Parliament rejected only by a very narrow vote (225 against 218) a statement that 'nuclear power could not be considered a safe and sustainable method of energy production and did not, therefore, belong in the policy against climate change' [2]. This highlights the total discrepancy between the argumentation of proponents on the one hand and ignorance of the potential of nuclear energy on the other.

There is a broad consensus in many countries all over the world that nuclear is not acceptable from a socio-political point of view and a different judgement on the criteria on sustainability that should be valid for all energy supply systems and should allow for neutral evaluations beyond different convictions and dualism of alternatives. So, there is a real need for establishing such criteria that would probably address a spectrum of aspects like [3]:

- Degradation of Resources (e.g. fuel, materials, land losses)
- Environmental Impacts (CO_2, SO_x etc.)
- Human Health Effects (acute and latent fatalities in operation and after accidents)
- Social Aspects (acceptance, risk perception, proliferation risk etc.)
- Economic Competitiveness (inclusion of external cost?)
- Avoidance of Non-Degradable Waste (e.g., amount, confinement time)
- Robustness (supply security, failure friendliness, grace periods etc.)

Strategies towards sustainable developments have not only to include the innovation potentials of the energy systems and the cost effectiveness [4] for CO_2-mitigation, but also to concentrate on the socio-political dimension of nuclear power [5] and to adopt the technology to the mechanisms for acceptance in a pro-active way.

2. Need for Innovation

The mechanism of 'evolution of species' is mainly driven by changes / evolution of the boundary conditions and those of other competitors to which the species have to respond by viable mutation or change of attitudes. The boundary conditions for nuclear energy have evoluted drastically in contrast to the expectations in the past decades. It is unrealistic to expect an adaptation of the social and economic environment to the intrinsic technical evolution of nuclear technology as often claimed by the nuclear community. In the contrary, nuclear technology also has to 'mutate' quick enough to keep pace for coping with the evolution of the requirements and that of competing techniques.

Nuclear energy still possesses a huge innovation potential like any other applied technique. But this potential has not been introduced strong enough into the discussion on the future of nuclear power and into the improvement of the market situation. There is a real danger that the future of nuclear power might be decided on the basis of the anticipated deficits of the nuclear technology established some decades ago not taking this potential for improvement into account. Successfully applied technical solutions, convincing operational experiences, advanced commercial projects and innovative approaches complement each other for a long-term option on nuclear power and for a progressive argumentation on future perspectives.

The reasons against nuclear energy are partially known from investigations / interrogations and the question arises whether technological innovations can respond to these fears, changed views and trends as being discussed for some selected examples in this paper. This applies for the public as well as for politic and industrial decision makers.

'Market' compatibility is a pre-condition for industrial engagement, acceptance and risk perception concerning the safety of investments and return of capital. **'Structural' compatibility** is needed to apply nuclear energy under effective & rational licensing, manufacturing and operation procedures. **'Environmental' compatibility** of nuclear power is often referred for defending the need for nuclear energy. '**Mental' compatibility** of nuclear technology might even be more important for reconciling nuclear energy with public opinion again.

These goals - in a long-term view - also represent a challenge for R&D on innovative technological approaches and should be fostered by a consensus within the nuclear community despite potential different views on technological options [6].

3. Different Levels of Acceptability

The acceptability of nuclear power is normally focused on the perception of the public and the politic level being mainly influenced by safety / waste concerns and other conflicts like credibility / communication problems and different political perceptions on future energy supply systems as it will be later discussed in more detail.

Another level that has to be addressed is the decline of acceptability for nuclear power by industrial decision makers. The actual mechanisms of industrial decisions on investments or engagement in nuclear energy are also a result of evolutionary - possibly irreversible - changes in the attitudes of industrial leadership, management and criteria (e.g. shareholder value, short term return of capital etc.) as well as the 'inverted' competitiveness of nuclear against low-priced and highly effective fossil-fired power plants. The 'safety' of investment is not only judged on a purely technical and financial basis but also by taking into account e.g., the 'risk' of changes in market structures, needs for back-fitting and danger of early shut-down by political influences or even draw-backs in other business areas due to the nuclear engagement. Normally, the risk for loss-of-investment and damages in case of nuclear accidents are also partially not accepted by insurance as it may be for other industrial projects.

The field of industrial acceptability of nuclear power is often assessed with a sentimental view to the 'good old times' when industrial leaders claimed for long-term perspectives and developments as well as for large investments with a long-term return of capital. Monopolistic structures in the electricity generation are also reduced in favour of free markets, competition and the possibilities for independent energy suppliers. The actual situation has to be analysed and 'accepted' as a basis for 'tuning' the technical concepts and economic features of nuclear power plants. The economic attractiveness of conventional power plants is also a result of drastic improvements in efficiencies and cost reductions using the benefits of series production and low-cost manufacturing of equipment in the world market. Long and complicated licensing procedures impose additional handicaps and risks on nuclear energy.

Another - but interconnected - area of 'risk perception' results is the still underdeveloped consensus on common strategies within the nuclear community especially with regard to innovations. Evolutionary incremental improvements may reduce the technical risk and the needs for extensive demonstrations, but they may possibly not keep pace with the evolution of requirements. Addressing innovative approaches in a dualistic view by the attribute 'revolutionary', indicates that innovations are judged to endanger existing technologies and installations.

It is rather essential that the nuclear community defines a consensus on the coexistence of different generations of established technologies and different options on innovative technologies and concepts. Such an 'internal' consensus and a visible willingness also to respond to the evolution of the social environment (e.g., by flexible innovation strategies) may be a pre-condition for an effective communication towards an 'external' public and political consensus.

The drastic beneficial changes by the globalisation and e.g., by the European Unification also have to be accepted and actively transposed into new collaboration structures on the industrial, administrative and R&D side instead of the acquainted former structures on national levels. The proposed 'Global HTGR R&D Network (GHTRN)' is also one step into this direction and could be a model for other technology developments.

4. Mechanisms of Risk Perception

Although probabilistic risk assessments (PRA) have proven as an adequate tool for balanced technical improvements of safety, the argumentation with the results of PRAs did not lead to improved public acceptance. And even much smaller probabilities or comparisons of risks associated to different energy supply scenarios might not really change the situation.

The reason might be that the risk defined as a linear product of damage and probability does not respond to the functional dependencies of the very essential human sense for the handling / acceptance of danger that permitted a survival of the human species since millions of years even under more dangerous and hostile conditions. All other human senses behave mainly in a non-linear way, so why this one?

It is a proven fact that the hemispheres of the human brain operate in different ways. Whereas the left side mainly balances rational intellectual input and experiences, the right side mainly reacts in an associative way. Both judgements influence the acceptability. This cannot be changed by the proponents of nuclear power and must be accepted as a God-given natural fact to which the use of nuclear energy must comply.

The following hypothesis for elaborating on an 'Acceptability Formula' has not to be taken too serious in a mathematical, analytical or even psychological sense. It should only indicate that the risk formula and their results may even be counter-productive in the communication with 'normal human beings'.

Everybody can check by himself whether the perception of danger has the same power than the probability of its occurrence. Nobody would play a lottery if he would judge it like a nuclear expert in probabilistics. There is a large personal potential benefit, with a limited amount of money as venture against a negligible probability for a significant prize. Obviously, the probability for that chance is strongly overestimated in the expectation of a huge benefit although a smaller gain is more probable. If the potential financial risk would be very much higher - e.g. the income of a whole month or even a year - the participation in lotteries would be reduced only to some individuals accepting that game.

Even in case of very tempting benefits there will always be an upper limit for the venture or damage otherwise it will not be accepted at all.

Higher potential damages - even the loss of life - are accepted, if there is the judgement of being able to influence the procedure by own skills either in games or e.g., by driving a car.

This is also willingly accepted even for a higher potential number of death by e.g., flying with a large aeroplane due to the believe in the skills of the pilot and the reliability of the plane and the airline. But panic reactions might result in the very moment when minor unusual disturbances occur.

Accordingly the 'Acceptance Formula' has to be enlarged by some other parameters describing the voluntariness, reliance in personnel / equipment and control of both.

The Institute for Decision Research in Oregon [7] referred to some more comprehensive qualitative risk and benefit characteristics as shown in Table 1.

Kind of risk consequence	*nature of risk source*
• voluntariness • possibility for avoidance • distribution over time • geographic distribution • degree of being affected • potential for control • social control • active influence • degree of familiarising / knowledge • scientific/technical maturity	• human, social, artificial risk • possibility for fleeing • sentiment for danger • reversibility / irreversibility • alternate possibilities • distance to the source of danger
dimension of risk consequence	*nature of benefit*
• fatal vs. limited damage	• exclusivity of benefit

• delayed vs. prompt damage • catastrophic vs. continuous damage • extreme catastrophes	• public vs. private benefit • distribution of benefit

Normally, only some of these parameters are being selected for simplified statistical reductions but for a complex acceptability problem like nuclear the full set of influences with different weights has to be kept in mind. Cultural / national influences may lead to some different weights or variations but the principle mechanisms are the same at least in a latent manner.

It is obvious that the risk formula does not at all respond to this complexity of judgements that human being are capable to perform in an indigenous way. This excellent result of human evolution also has to be respected within the argumentation on nuclear energy and to be transposed into technical and structural requirements for reconciling nuclear with the mechanisms of acceptability.

5. Technological Consequences from Risk Perception Mechanisms

Some of the 'Factors in the Acceptability Formula' can indeed be addressed by technological / structural convergence with these parameters as e.g.

Qualitative Risk / Benefit Characteristics	**Potential Response**
possibility for avoidance	independent barriers, self-acting safety systems
potential for control	Accident Management Measures (Fire Brigade)
social control	transparent' technology and surveillance
degree of familiarising / knowledge	neutral competent information
scientific / technical maturity	open information on the technological progress
fatal vs. limited damage	restriction of max. releases
delayed vs. prompt damage	larger grace periods
catastrophic vs. continuous damage	transmutation of waste into short-lived material
extreme catastrophes	deterministic exclusion by design
possibility for fleeing	slow accident progression
sentiment for danger	open information on all abnormal situations
reversibility / irreversibility	restricted max. release
alternate possibilities	neutral comparisons, sustainability criteria
distance to the source of danger	siting, underground construction
distribution of benefit	lower local electricity cost near to NPP

These few examples show that the trends for advanced and innovative designs are on the right orientation for coping with these anticipated parameters and that recent licensing requirements requesting restriction of maximum releases and inclusion of core melt accidents in the design as well as the need for a cooperative communication can be correlated logically.

The technological innovation potential for addressing these factors are not being discussed in an open way mainly because of the 'risk' perceived by the nuclear community itself with regard to potential negative consequences for older designs.

The distribution of the benefits to the whole community while concentrating the risk on the neighbourhood of the power stations is in disagreement to the assessment of social justice. The price for fuel is often lower near to the refineries. Why should the surrounding municipalities of NPPs not benefit by lower electricity cost?

6. Specific Objections against Nuclear Energy

The reasons to reject nuclear energy that are mainly mentioned in public debates and inquiries are referred to in [8]. They can be categorised according to their degree of relevance and cross checked whether technological innovations or alternate approaches or structures can have an influence on that according to the personal judgement of the author.

Category A: very important objections / doubts

Objection	Technological / Structural Response
Health damage / death by radiotoxic emissions	improved designs, barriers and filters
Equal chances for energy alternatives	support emission-free alternatives by low-cost nuclear energy
Restrictions/burdens for future generations	improved decommissioning, waste reduction, waste transmutation
Democratic control of the 'Atomlobby'	dissolving the confrontation on nuclear energy
Interweaved spheres of interest	transparent separate structures
low efficiency of public control	less formal, more pragmatic 'open' procedures

Category B: important objections / doubts

Objection	Technological / Structural Response
Enlarged damage by terrorist attack	reinforced structures, grace periods for AM
Technical risk of catastrophic dimension	Exclusion of catastrophic releases by design
Environmental damage by radiotoxic emissions	Exclusion of catastrophic releases by design, reduced operational releases
Impediment of better alternatives	'Coalition' & Support for introduction / subvention of alternatives
Potential for extortion of governments	reinforced structures, supervision
Proliferation of atomic weapons/materials	modified fuel cycles, burning of actinides

Category C: minor important objections / doubts

Objection	Technological / Structural Response
Enlarged damage by war	De-fuelling, underground siting
Environmental damage by waste heat	Co-generation (CHP), improved efficiencies
Tendency for environmental damage	'good-neighbour design'
Large electricity deficit after accidents	Reduced size of units, SMR
Dependency from Uranium supply	Stockpiles, high conversion, Thorium use
Restrictions in personnel rights (terrorists)	Robust designs, underground siting

Surveillance System ('Atom-State')	general problem (e.g. 'Oeko-State')
Restricted ability for defence	De-fuelling, underground siting
Restricted control of nuclear techniques	'Transparent' structures
Small participation chances	Open response on public concerns
High degree of estrangement	improved information / education

The examples show again that technological, structural and communicative responses are in principle also possible concerning most of the objections and fears. The evolutionary trends for advanced and innovative reactor designs and technologies are mainly coherent with these requirements from public judgement. In some cases the congruence of innovations or design improvements is even given by other reasons e.g. coping with internal impacts (hydrogen / steam explosions, missile impact) leads to robust containment structures as improved shelter against terrorist attack.

Even an underground siting for future NPPs as proposed for some American designs (MHTGR, PRISM) could be reconsidered if the aspects of improved shelter against terrorism and potential war would be decisive for acceptance (e.g., Sacharow and von Weizsäcker turned from pro-nuclear to anti-nuclear mainly due to this reason).

The security of electricity supply in times of shortages in energy supply or other crisis lead in some countries to enormous efforts on keeping own primary energy sources (e.g. hard coal mining, gas and oil storage). The judgement that they are safe is taken from the fact that they are underground-sited and always available even in critical situations. NPPs in such locations would - in contrary to the above mentioned assumption - represent a safe and reliable energy source even in a crisis.

Those reasons are of course strongly influenced by the general political situation and may be less important in times of globalisation, global inter-dependencies and safe / sufficient energy supply.

Other aspects have possibly also inverted since the end of the 'cold war' as the danger from proliferation is more due to the disarmament of weapon heads and huge amounts from that materials. It is not yet commonly known or accepted that nuclear reactors are able to destroy weapon-grade material but the nuclear community itself has not yet concluded on adequate techniques being optimised for that purpose or on the co-existence of different solutions. So, why should the public accept this as an argument in favour of nuclear reactors?

This situation of internal dissent of nuclear actors is given for many technological alternatives or responses as indicated above hindering consequent and flexible innovation approaches on public acceptance matters. A pro-active technological response based on a consensus within the nuclear community would possibly help to create new arguments for the nuclear case instead of blocking persuasive measures for destroying this sensitive material by ever-lasting discussions on technical alternatives. This attitude is not very much different from that of opponents arguing for some future alternate energy supply systems instead of nuclear.

The credibility of the nuclear community and its arguments would significantly increase if 'quasi-religious wars' and dualistic views on specific reactor lines and technical preferences from the past would be stopped in favour of credible innovation efforts coping with the actual and up-coming challenges for the nuclear case. It would also increase the credibility if the motivation for innovation and technological evolution would be based on the adaptation of reasons that are stemming from the psychological mechanisms for acceptability and from clearly defined reasons for objection and fear.

7. Conclusions / Deficits

Decisive for the acceptance of specific technologies may be the fact [9] whether they are judged as a 'limited risk' with a balancing of benefits and disadvantages or as a 'real fundamental danger' that has to be eliminated as such. This also influences the role either to use a technology in an active way or only being passively afflicted by it. Several other parameters influence the mechanism of acceptance in a rather complex way so that the - probabilistic - argumentation by the 'Risk Formula' does not seem to be adequate at all, especially for non-experts. The limitation of the plausible threat on the one side and of the quasi-eternal threat by nuclear waste - also by technological innovations concerning the safety of NPPs and the reduction / transmutation / safety of waste - may be a precondition for re-starting a rational acceptance debate.

Other objection against a technology may additionally result from

- pure conservatism
- negative cost /benefit relation
- exclusion from control and participation in technology development and application /use
- ecological goals
- reduced believe in technical progress
- social development into the direction of a 'Risk Society'

The industrial acceptance of nuclear energy is also threat by the 'risks' from these influences and reduced economic margins whereas the nuclear community still has to define a consensual strategy for responding to the overall acceptance situation and for the role of innovations.

Technologies are always judged as a socio-technical system within the social context of their development, control and application as well as their incorporation in political decision processes and the credibility of control.

The actual acceptance problems do not represent a general objection against innovations and are also not specific for certain countries. In some variation they are existing in all highly industrialised societies with some variation of the general scheme and mechanisms. Federalism, decentralisation and low national identification may influence the difference of interest between those who develop and apply a technology and those who feel threat by it. Mass media generate enhanced attention and especially offer a public forum for criticism and politicisation of conflicts with regard to specific technologies.

The risk / technology controversy is not a temporary pathologic effect but a characteristic of modern societies. It is very important to handle this conflict in a positive way and to develop - as a 'social innovation' - a culture of communication and dispute in conjunction with technological innovations that respond to the mechanisms and needs of acceptability.

Such an environment may help to get nuclear energy back into the row of candidates for sustainable technologies.

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