HEINRICH BÖLL STIFTUNG

Myths about Nuclear Energy

How the energy lobby is pulling wool over our eyes

by Gerd Rosenkranz

Berlin, April 2010

Heinrich-Böll-Stiftung
Die grüne politische Stiftung

Schumannstraße 8 10117 Berlin
Telefon 030.285 34-0 Fax 030.285 34-109 **www.boell.de**

Preface: Nuclear Energy – a Dead End

Anyone following the statements expressed from time to time about the renaissance of nuclear energy could get the impression that the number of new nuclear plants was increasing at an immense and steady rate. In fact, more recent statistics show 60 plants in the process of being built, the majority in China and others in Russia, India, South Korea and Japan. The USA is only shown as having one actual building project. However, this list (the VGB Power Tech) includes numerous ancient projects that were never completed and are therefore de facto building ruins.

Moreover, there are at the present time proposals for about 160 new nuclear power plants up to the year 2020, 53 of these in China alone and 35 in the USA, followed by South Korea and Russia. In Europe, the UK heads the list with eight proposed new projects, followed by Italy, Switzerland, Finland, Rumania and Lithuania. France, that would like to bless the world with new nuclear power stations, is itself only planning one new plant. Most European states are not entertaining any concrete nuclear plans.

As a matter of fact the number of nuclear power plants in the world is continually decreasing. At the present time there are still 436 reactors in operation. In the next 15 to 20 years more ageing plants will go offline than new ones coming into operation. By no means will all declarations of intent be implemented. The more energy markets are opened up to free competition, the smaller the chances are for nuclear energy.

The costs for new plants are also exploding. For example, the building cost of the new nuclear power plant in Finland's Olkiluoto has already increased from 3 to around 5.4 billion Euros although not even the shell of the building is standing yet. In addition, there are the unsolved problems of waste disposal and the high susceptibility of the technology to failure. Today, no privately run energy conglomerate risks building a new nuclear power station without government subsidies and guarantees. It is noticeable that new nuclear power stations are built particularly where the government and the energy industry form an unholy alliance.

Up to now, nuclear power plants have been funded by massive public subsidies. For Germany the calculations roughly add up to over 100 billion Euros and this preferential treatment is still going on today. As a result the billions set aside for the disposal of nuclear waste and the dismantling of nuclear power plants represent a tax-free manoeuvre for the companies. In addition the liability of the operators is limited to 2.5 billion Euros – a tiny proportion of the costs that would result from a medium-sized nuclear accident. All things considered nuclear energy proves to be just as expensive as it is risky.

In addition to the routine arguments about nuclear energy, there are some new ones. Firstly, the danger of nuclear proliferation is growing in proportion to the number of new nuclear power stations all over the world. There is no insurmountable division between the civil and military use of this technology in spite of the efforts on the part of the International Atomic Energy Agency (IAEA) to regulate this. The most recent example is Iran. At the end of the day anyone who does not want to be regulated cannot be forced to do so. With the expansion of nuclear energy there is a growing necessity to build reprocessing plants and fast breeders in order to produce nuclear fuel. Both give rise to the circulation of plutonium leading in turn to the creation of huge amounts of fissile material capable of making bombs – a horror scenario!

Secondly, an extension of the life span of existing nuclear energy stations, and even more so the building of new plants, would act as a massive brake on the development of renewable energies. The claim that nuclear energy and renewable energies complement each other is a myth since not only do they compete for a meagre amount of investment capital and power-lines but at the same time

nuclear plants limit the growth potential particularly of wind energy owing to their inflexible continuous operation. On windy and low-consumption days the energy demand in Germany is already covered to a large extent by the wind energy supply. As the output of existing nuclear power stations (as well as the big coal-fired power stations) is not reduced at short notice for economic reasons, the surplus energy has to be exported to other countries at a loss. There is method in this madness.

Whatever way you look at it, nuclear energy has neither the potential to make a decisive contribution to climate change nor is it necessary in order to guarantee energy supply. The exact opposite is true. Those who want to promote the development of renewable energy with the aim of producing 100% of the power demand should oppose the building of new nuclear plants as well as the life span extension of older ones. Despite the claims about nuclear energy it is not a suitable interim strategy leading towards the age of solar energy.

Berlin, January 2010

Ralf Fücks (Chairman of the Heinrich-Böll-Stiftung)

Introduction: Forsmark – 22 Minutes of Fear and Terror

It is 25 July 2006 in the middle of the day at 13.19 hours when electricians carrying out maintenance work outside the central Swedish nuclear power station at Forsmark trigger a short circuit at a substation. Such things happen repeatedly wherever gigantic turbines turn and enormous amounts of electricity have to be conveyed from large block unit power stations. Normally, a malfunction such as this in a nearby electricity grid does not create serious difficulties for any nuclear plant. The safety systems are geared up for this. The reactor is separated from the malfunctioning grid before the short circuit outside reaches the electrical system inside. In the worst case scenario the reactor switches itself off automatically and since the heat producing decay of the radioactive inventory in the core of the reactor continues for days the reactor is gradually brought into a non-critical state by means of the emergency cooling systems.

But on this Tuesday nothing is normal at Forsmark. As the separation from the grid takes place too slowly and because the failure – in itself nothing out of the ordinary – unleashes a torrent of further complications, most of the electrical system in Block 1 of the boiling water reactor collapses. Two of the four diesel generators which are supposed to supply the reactor control system and the emergency cooling pumps with electricity in the case of an emergency fail to start. For 22 agonising minutes during the most critical phases of the emergency the screens in the control room remain blank. The measuring sensors send no signals about the nuclear chain reaction in the core of the reactor; even parts of the loudspeaker system for the purpose of raising the alarm and signalling evacuation stay silent. There is an absence of vital information about the position of any of the control rods which regulate the chain reaction in the reactor core or about the level of the cooling water in the reactor vessel. It is only when a technician finally manages to start the non-functioning diesel engines by manually pressing a button and thus supplying the central measuring and security systems with electricity again that the blind flight of the reactor finally comes to an end.

The Swedish Atomic Regulatory Authority (SKI) soon identified the failure of two AC converters as the main cause for the escalation in the boiling water reactor Forsmark 1. As a result of this, two out of a total of four emergency back-up generators did not switch on as they should have. However, due to the breakdown of substantial sections of the monitoring system of the reactor, it was

extremely difficult to reconstruct the exact course of events afterwards. The most worrying aspect of all was that experts could not explain why identical AC converters which had managed to start the two remaining generators in the normal way had not reacted to the interference voltage peak in the power supply of the reactor in the same way as the two others. The only certain thing in the end was that if they had done so, the reactor would most probably have gone out of control. Then all four cables of the reactor's safety system would have been affected and this, as the SKI admitted, would have led to "the electricity supply in the whole emergency power system being cut off resulting in a scenario not covered in the reactor's security guidelines" (Society for Plant and Reactor Security 2006). There was no provision for this kind of failure in any manual, there were no regulations to deal with it and, indeed, no possibility for doing so.

First Myth: Nuclear Energy is Safe

What happened on the east coast of Sweden in the middle of that day in the summer of 2006 was a fatal reminder of two events that have cast a warning shadow over the civil use of nuclear energy for decades: the catastrophes at the atomic power stations of Harrisburg (in March 1979) in the US and Chernobyl (in April 1986) in the Ukraine.

A barely understandable lack of planning, the incorrect installation of important components, unforgivably sloppy maintenance and not least a naive trust in a highly sensitive technology – none of this was new to us: not only because of Harrisburg and Chernobyl but also the reprocessing plant in Sellafield in England, the Japanese breeder reactor, Monju, the reprocessing plant at Tokaimura in Japan, one of the spent fuel storage pools at the Hungarian nuclear station, Paks and also the German nuclear plants at Brunsbüttel and Krümmel on the river Elbe. Wherever humans are working, mistakes are made. We can count ourselves lucky that the chain of errors repeatedly deemed 'inexplicable' after every accident does not always result in such catastrophic consequences as in the Ukraine and its neighbouring countries in 1986. In Block 1 of the atomic power station at Forsmark, a good 100 km north of the Swedish capital Stockholm, it only resulted in 22 minutes of fear and terror for the reactor's personnel on site and some grave doubts about the reliability of the reactor operator, Vattenfall. Since that time the northern state-owned conglomerate has also caused nagging doubts to be raised elsewhere, namely at the German sites of Brunsbüttel and Krümmel.

Since then the name Forsmark has been synonymous with supposedly the most critical accident in a European nuclear reactor since the catastrophe at Chernobyl. Experts at home and abroad who tried to reconstruct the events of that day came to the shocking conclusion: it could have been much worse and worse can happen at anytime.

The residual risk of forgetting

The advocates of nuclear energy in many industrialised countries take obvious delight in what they call the 'de-ideologisation' of the conflict surrounding this energy. In view of climate change and an ever-increasing shortage of fossil energy sources, the tone is said to have become "calmer and more reasonable". In particular the supporters of nuclear electricity production are jubilant about this easing of tension unless there happens to be an election looming. For decades the political-societal debate has moved away from the fundamental safety issues of nuclear energy to questions about the economy, climate protection, the conservation of resources and the safeguarding of energy supplies. In public perception, nuclear energy could thus become one technology among many, its use being

simply a question of weighing everything in the same way as choosing between coal and natural gas power stations.

Nuclear fission is thus becoming increasingly integrated into what economists have defined as the triangle of the political energy debate consisting of economic viability, safeguarding energy supplies and the impact on the environment. The fact that safeguarding against catastrophes is not an aim of nuclear energy is of less concern to its supporters. On the contrary they are extremely satisfied. Supporters of nuclear energy are becoming increasingly successful at concealing this technology's unique potential for catastrophe behind a wall of arguments, all of which have one main purpose: to distract from the fundamental questions of safety. This development is not a coincidence. It is the result of a strategy which has been pursued doggedly and deliberately for many years by the operators and manufacturers in the leading nuclear energy countries.

A successful campaign of distraction may well quieten public debate for a time but the probability of a huge catastrophe does not reduce the necessity for such debate. The danger of the ultimate catastrophe, i.e. an accident which exceeds 'the greatest imaginable catastrophe' catered for in the security systems and the fact that it can never be excluded has been and is the prime cause for the fundamental conflict surrounding nuclear energy. The arguments first and last against this form of energy conversion are based on this very real danger on which the whole acceptance of nuclear energy stands and falls – regionally, nationally and internationally. Since Harrisburg and even more so since Chernobyl the nuclear energy industry has pinned its hopes on winning back public support for this technology at some point with the promise of 'catastrophe-proof' nuclear reactors. As early as three decades ago constructors made a great promise under the banner of 'an inherently safe nuclear power station'. The Americans called these reactors of the future 'walk-away reactors' in which a meltdown or similarly serious accident was physically out of the question thanks to so-called passive safety systems. At the time the leading manager of an American nuclear reactor construction company commented enthusiastically: "Even in the case of the worst of all imaginable accidents, you can go home, have lunch, take a nap and then come back without the slightest worry or panic" (cf. Miller, 1991). This boastful announcement has remained up to now what it was then: a bad cheque for the future. The technology historian Joachim Radkau suspected as early as 1986 that the 'catastrophe-proof' reactor was a "pipe-dream constantly bandied about under false pretences in times of crisis but never to become a reality." (Radkau 1986) This is how it has remained.

In the meantime, the European Atomic Energy Community (Euratom) and ten nuclear energy producing countries are taking a neutral approach to 'Generation IV' which, in the distant future, is due to replace existing reactors or those being planned. Even reactors of the next but one construction phase, with their innovative security systems, are no longer claimed to be idiot-proof which their predecessors are still regarded as being. But they will be more economical, less susceptible to military misuse and, as a result, more acceptable to the general public. The first of these reactors are expected to be supplying energy around 2030. That is the official version. Unofficially, even some of the high profile supporters, such as the former president of the French energy supplier Électricité (EDF), François Roussely, do not expect commercial operation to begin before about 2040 or 2045 (cf. Schneider 2004).

In the absence of a promise that a fourth generation of reactors would be absolutely safe, the nuclear energy industry has quietly buried the guarantees of the past. In the meantime, even in day-to-day operation relative safety has to suffice. In concrete terms this adds up to nothing more than the sweeping claim happily bandied about by non-experts in the politico-journalistic field that "our reactors are the safest in the world." There has never been any sustainable evidence establishing the degree of truth behind this assertion which has found particular favour in Germany. And it is not exactly plausible that nuclear power stations, whose construction started in the 1960s and 1970s and

which had therefore been designed in the 1950s and 1960s with both the knowledge and the technology of that time, should be able to offer a satisfactory level of safety today. However, as long as no one prevents the nuclear energy supporters in France, Sweden, the USA, Japan or South Korea from claiming the same of their own reactors, they all live happily with their respective slogans. In fact there is no nuclear community in any country that does not consider its own nuclear power stations to meet global standards – or at least publicly makes this claim. As a result of the arms build-ups of the last 15 or 20 years even in Eastern Europe claims are increasingly heard that Soviet constructed reactors meet Western safety standards or even exceed them in many respects. Incidentally, there is no need for any formal agreement on the terminology used; the general message worldwide seems to be: "There is no cause for concern".

In fact concern is actually lessening in many countries especially with a generation of politicians for whom accidents like at Chernobyl or Harrisburg are no longer a significant event. An important question to be asked therefore concerns the price mankind has to pay for absolute peace of mind on the nuclear front. What does this mean for international nuclear energy safety when narrowly avoided catastrophes such as that at Forsmark in Sweden are debated in public for only a few weeks but after that only among committees of experts behind closed doors?

The comparatively high level of security of German reactors was actually attributed in the past, even by supporters of nuclear energy, to the strength of the anti-nuclear energy movement in former West Germany – a continuous sceptical monitoring of nuclear power stations as a result of a highly sensitised population. If this interpretation is correct, it was only the penetrating questions and the establishing of a 'critical expert public' which ensured that nuclear power stations became the industrial sites with the most extensive preventative measures against breakdowns and accidents in economic history. They still are today. Unfortunately it is to be feared that the reverse is also true: when public attention wanes or is not even tolerated as under authoritarian regimes, safety decreases.

Those who want to continue using nuclear energy even after Chernobyl and Harrisburg like the Christian-Democrats (CDU) and Liberals (FDP)[1] coalition government of Germany, in the end have to face the question of whether they want to do so until another catastrophic accident eliminates the option of nuclear energy once and for all. One thing is certain: no-one in Europe or the USA would talk about the 'renaissance of nuclear energy' or would be discussing prolonging the life spans of ageing reactors if, at Forsmark on July 25, 2006 in Sweden, not two but four of the AC converters had failed and Sweden of all places, prized as a high-tech country, had been the scene of this disaster. Northern and western Europe would not only have been confronted with the suffering of millions of people. Moreover, with 130 nuclear reactors the continent would be spending many years dealing with the physical and mental reconstructions and the economic collapse caused by this catastrophic scenario which would have overshadowed the present financial and banking crisis by far. Every country with a significant portion of its electricity supply dependent on nuclear energy would have to face black-outs on a scale hitherto unknown in most of the countries of the European Union for decades. At the same time there would have been an increased impact on the environment as many of the fossil fuel powered stations still available would have had to operate round the clock in a way never intended in order to make up for the energy shortfall brought about by the shutting down of nuclear plants under pressure from a deeply distraught public. It did not come to that at Forsmark, thank God.

The insidious poison of routine

[1] Conservative CDU and pro-business FDP coalition

No one seriously denies that of course nuclear energy has also gained from the progress made in the general technological development of the last decades. The revolution which has taken place in information and communication technology since the construction of the majority of commercially operated reactors in the world makes the controlling and monitoring of a nuclear power station more transparent and more reliable in its day-to-day operation. When the older reactors operating today were at the drawing board stage computers were still using punch cards. Modern operating systems have been and are being installed retrospectively even in many of the ageing reactors. A better understanding of the physical workings and other complex processes in the normal day-to-day running of a reactor and even more so in cases of failure that is achieved by means of computer simulations and experiments also means a higher level of security. These days reactor operators play out complex computer simulated accident scenarios which could not even have been designed 20 or 30 years ago and were therefore completely unknown. Security technicians also profit from advance probability analyses and more refined testing and control systems with which even the older reactors are gradually being equipped. Reactor operators also claim to have learnt from Harrisburg, Chernobyl and the serious accidents in Japan. They point to the World Association of Nuclear Operators (WANO) that today organises an exchange of information and ensures that accident data are swiftly passed on to its members. In 2010 reactor operators all over the world will be able to have access to the experience of around 13.000 years of reactor operations.

However, this is by no means a guarantee of quality 'new security' for nuclear power stations. The fact that there have been no nuclear core meltdown accidents since 1986 does not mean it could not happen again. Forsmark was simply the loudest warning shot in recent times; further warnings followed in German reactors at Brunsbüttel and Krümmel with the result that these reactors did not supply any electricity for several years. About three-quarters of the reactors in the world are the same as those at the time of the Chernobyl disaster. It is in the very nature of probability that a serious accident could happen today or in 100 years' time. Therefore 13.000 years of reactor operations provide no evidence to the contrary. When the nuclear energy industry faced its first core meltdown in a commercial reactor in Harrisburg in 1978, anti-nuclear protestors in Germany distributed leaflets pouring scorn on the pompous promises of safety made by nuclear technicians: "an accident every 100.000 years – how time goes by!".

An increase in the intended life span of the reactors that is promoted worldwide is described by nuclear plant operators as "unreservedly justifiable from the point of view of security" (Frankfurter Rundschau, 12 August 2005). Walter Hohlefelder, president of the German Atomic Energy Forum lobby and formerly the chairman of the nuclear energy operator E.on, declared in all seriousness that such an extension of the life span of reactors "made the electricity supply more secure" (Berliner Zeitung, 9 August, 2005). The most astonishing thing about such claims is that they are no longer challenged by sections of the public, especially by the politicians who support nuclear energy. For it really is an audacious claim that nuclear plants – in contrast to cars and planes – become safer the older they get. Unfortunately, this not only defies common sense; it also contradicts the laws of physics.

The global arsenal of reactors is 'growing old'. Behind this simple layman's terminology lurks a whole body of knowledge – materials technology and metallurgy – which does not only cover the simple 'signs of wear and tear' but also highly complex changes on the surfaces of and within the metal components. Processes of this kind in the micro area of nuclear structures and the resulting consequences are difficult to forecast and reliably detect in good time via the monitoring systems – especially when high temperatures, enormous mechanical stress, a chemically aggressive environment and the continual bombardment of neutrons from the nuclear fission simultaneously affect the security relevant construction elements which are difficult to reach. Again and again in recent decades there have been incidents of corrosion, radiation damage and crack formations on the

surfaces and on the welded joints of central components – even on the inside. Serious accidents have often been avoided because the defects were discovered just in time either by the monitoring systems or through routine checks during periods of shut down and inspection. Yet again and again the timely discovery of serious damage can simply be put down to chance.

This situation has been exacerbated in many countries as a side-effect of the liberalisation and de-regulation of energy markets. Liberalisation calls for greater 'cost awareness' on the part of the reactor operators in every power station – with direct consequences: e.g. staff redundancies, cutting back on periodic security checks, shorter dead-lines and consequently greater time pressure when it comes to inspections and fuel changes. Quite clearly none of this increases security.

Preliminary conclusion: if reactor operators succeed in realising their concept of a life span of 40, 60 or even 80 years for nuclear power stations, the average age of nuclear plants operating in the world which was 24 years in 2007 will increase massively in the future. The risk of a serious accident will thus increase considerably. Even the construction of new reactors of the so-called Generation 111 will have little effect on this. For decades they will still only account for a small proportion of the reactor arsenal world-wide. Moreover, a serious accident even in these reactors cannot be discounted. The European Pressurised Reactor (EPR) , for example, which has been on the drawing board since the end of the 1980s – the prototype of which has been in construction in Finland since 2005 – is, according to critics, nothing more than 'half-hearted' further development of the pressurised reactors operating in France and Germany at the moment. The idea is that the consequences of meltdown are contained by means of a complicated system of catching the melted reactor core – 'core-catcher'. The result of this concept which considerably increases the cost of the whole plant has been, among other things, that reactors have had to be designed in the development stage to be more and more efficient in order for them to remain economically competitive both within and outside the field of nuclear technology.

There is certainly no consensus of opinion even among reactor operators that the probability of a serious accident has decreased in real terms through operational experience and the prolonged life spans of individual reactors. Anything else would actually amount to a denial of reality in view of the high number of serious failures which cause a stir around the globe again and again.

The (naturally not complete) list of potentially catastrophic situations in the recent past includes:

- A burst pipe in the residual heat removal system in the French pressurised reactor Civeaux 1 whereby the primary cooling circuit lost 30 cubic metres of cooling water per hour until the leak could be isolated and the situation stabilised (1998);

- The manipulation of security data at the English reprocessing plant at Sellafield and the Japanese nuclear energy station, Tepco (1999/2002);

- Damage to nuclear fuel elements never seen before in Block 3 of the French reactor Cattenom (2001);

- A serious hydrogen explosion in a pipe at the boiling water reactor at Brunsbüttel in Germany in immediate vicinity of the reactor pressure tank;

- Massive corrosion of the reactor vessel in the US reactor Davis-Besse that had remained undiscovered for years whereby only the thin steel lining of the reactor boiler prevented a catastrophic leak when in full operation (2002);

- The dramatic overheating of 30 highly radioactive nuclear fuel elements in the neutralisation pond at the Hungarian nuclear energy station, Paks, which finally shattered to pieces like porcelain under a torrent of cold water in the attempt to cool them down from a temperature of 1200 degrees Celsius and prevent a possible atomic explosion in the unprotected area of the reactor complex (2003) (Heinrich-Böll-Stiftung 2006);

- Serious earthquake damage at the Japanese reactor complex Kashiwazaki, resulting in transformers catching fire, the leakage of radioactive liquids and finally a shut down lasting years (2007);

- A transformer fire in the German power station Krümmel which initially led to smoke formation in the switch room and consequently to serious failures in the fast shut down system. Almost exactly two years later, just a few days after being put into operation, there was another short circuit in one of the transformers, oil leaked out and the reactor was quickly shut down. However, on this occasion the transformer did not catch fire (2007/2009).

In the meantime such obviously unavoidable incidents caused more concern and awareness of the problems among the reactor operators than among the supporters of the nuclear renaissance. And that is not simply because the damage and loss caused by failures and accidents add up to billions for the reactor operators.

Those in positions of responsibility in nuclear plants are more and more worried about the consequences of a phenomenon deeply-rooted in human beings: their susceptibility to the insidious poison of routine which makes it almost impossible to carry out monotonous and repetitive actions year in and year out with the highest degree of concentration at all times. During a WANO conference in Berlin in 2003 speakers bluntly broached the subject of what was in their opinion rampant negligence and self-satisfaction on the part of reactor operators. It was a Swedish participant of all people in this gathering of experts who warned that both were “a danger for the survival of our industry” (Nucleonics Week, 6 August 2003). The former Japanese chairman of WANO, Hajimu Maeda, diagnosed “a terrible illness” that was threatening the industry from within. It began with a loss of motivation, self-content and “negligence in maintaining security standards owing to the pressure of cost brought about by the de-regulation of energy markets”. This illness had to be recognised and confronted. Otherwise at some point “a serious accident [...] [will] destroy the whole industry” (Nucleonics Week, 6 August 2003). When three years later, during the Forsmark disaster, new cases of negligence in the management of the reactors of the Swedish nationalised company, Vattenfall, kept coming to light this concern proved to be all too prophetic.

Second Myth: The Dangers through Misuse and Terror can be Controlled

A completely new dimension of the threat has arisen as a direct consequence of the terrorist attacks of 11 September 2001 in New York City and Washington, D.C., heightened still by the statements made later by the detained masterminds of the attacks being questioned. The new dimension of terror which the leading powers of the West experienced as a result of the attacks on the USA had never been considered in previous examinations of security questions. But it is precisely this development that calls for a fundamental re-appraisal of the use of nuclear energy and the enormous risks associated with it.

Going by the admittance of two imprisoned Al-Qaeda leaders it is an undeniable fact that the targeting of atomic power stations actually does play a part in the plans of Islamic terrorists. According to their statements which can be found in the official report of the US senate on the attacks (National Commission on Terrorist Attacks Upon the United States 2004) Mohammed Atta, who later flew a Boeing 767 into the North Tower of the World Trade Centre, had already chosen the two reactor blocks of the Indian Point power station near the Hudson river as a possible target. The attack on the nuclear power station only 40 miles away from Manhattan even already had a codename – "electrical engineering". However, as the terrorist pilots thought their approach to the power station could be cut off by flight defence rockets or interceptor jets, the plan was in the end rejected. In fact, no such military security provisions had been made. The terrorists' decision to drop the plan was based on an error of judgement. The Al-Qaeda leader Khalid Sheik Mohammed actually stated that his original even more monstrous plans included the simultaneous targeting of several nuclear power stations by a total of ten hijacked planes. It is therefore imperative that scenarios of terrorist attacks play a far more prominent part than has previously been the case in the risk assessment of nuclear power stations. The likelihood of attacks of this kind has increased dramatically since 11 September 2001.

At the same time it is generally undisputed that none of the 436 reactors in operation around the world at the beginning of 2010 could withstand the deliberate attack of a large fully-tanked aircraft. Whilst still reeling from the attacks in New York and Washington even German reactor operators were unanimous in confirming this. Admittedly the chance crash of small aircraft and military planes had been taken into safety considerations in the construction of many nuclear power stations in the Western industrial countries. However, the chance impact of a large fully-tanked passenger plane was considered so unlikely that in no country effective precautions had been taken against a scenario of this kind. The idea of a deliberate attack by a passenger plane converted into a missile had simply been beyond the imagination of the reactor constructors.

In Germany the Cologne based Company for Plant and Reactor Safety (GRS) launched an extensive survey into the vulnerability of German nuclear power stations to air attacks immediately following the attacks in the USA. The survey – on behalf of the German government – not only ascertained the stability of typical nuclear power stations but in addition half a dozen pilots using a flight simulator at the Technical University of Berlin carried out thousands of attacks of varying speeds, impact sites and angles on nuclear power stations operating in Germany, life-like video animations of which were relayed into the simulator-cockpit. Some of the test pilots – like the terrorist pilots of New York and Washington – had only flown smaller propeller planes before. In spite of this, roughly every other simulated kamikaze attack was claimed to have been a strike.

The findings of the investigation proved to be so alarming that they were never made public. Only one summary of events classified as 'highly confidential' became available to the public (Society for Plant and Reactor Safety 2002). According to this, especially in the case of the older power stations, each strike regardless of the type, size or impact speed of the passenger plane threatened a nuclear inferno. Either the 'shell' would be directly penetrated or the pipe-work system would be destroyed by the enormous vibrations caused by the impact and the kerosene then catching fire.

In every situation, core meltdown and the widespread release of radioactivity would have been the likely consequence of a successful strike. Even the intermediate storage facilities within the power station where burnt out fuel elements decay in water basins are considered to be at extreme risk. In Germany, nearly ten years after the terrible attacks in the USA, there is still no concept for safeguarding nuclear power stations against attacks of this kind. Plans of the former Social Democrats-Alliance 90/the Greens coalition government to make power stations invisible for a short time with a system of smoke dischargers in the event of an air-attack led nowhere. After the German

Federal Constitutional Court categorically ruled out the deliberate shooting down of civilian planes with innocent passengers on board in February 2006 the idea was laid to rest. The aim of discharging smoke had been to shroud the nuclear power stations in artificial smoke until fighter jets of the armed forces were airborne and were able to ward off the hijacked plane and shoot it down if necessary.

Suicide attacks would put 9/11 in the shade

The scenario of 'targeted air attacks' did nothing to remove other fears that had already been under international discussion before 11 September 2001. They were simply given a concrete and more realistic foundation. There had long been intensive research into terrorist attacks in which nuclear plants are attacked on the ground by modern tank and bunker penetrating missiles or explosives or whereby the attackers manage to gain violent or secret access to security areas. However, the scenario of attackers who are prepared to accept their own death had not been taken into consideration. The shocking possibility of people carrying out suicide attacks on a nuclear power station knowing full well that they themselves will be the first victims conjures up scenarios that had never been contemplated before.

From the point of view of extremist suicide bombers an attack on a nuclear plant is by no means irrational. On the contrary, extremists know that a 'successful' attack would not only unleash an immediate inferno and cause suffering to millions of people but would also, quite probably, result in the shutting down of numerous other nuclear plants as a precautionary measure thereby leading to an economic tremor far eclipsing the financial shock waves experienced in the aftermath of 11 September 2001. As monstrous as the attacks on the World Trade Centre and the Pentagon were, their principal aim was nevertheless demonstrative and symbolic – to strike at the economic, political and military heart of the superpower, USA, and thereby humiliate it. The attack on a nuclear plant would not be symbolic in the same way. It would affect the electricity supply and thus the nerve centre – short, the whole infrastructure of an industrialised country. The radioactive contamination of a whole region and possibly the lasting evacuation of hundreds of thousands if not millions of affected people would wipe out the dividing line between war and terror once and for all. No other attack on the industrial infrastructure, not even on the oil depots of Rotterdam would have a similar psychological effect on Western industrial countries. Even in the case of it not actually succeeding in unleashing a super catastrophe, the result would be devastating. In the aftermath of an attack of this kind the debate would intensify the conflict surrounding the risks of catastrophe of nuclear energy as never before and probably lead to several industrial countries shutting down many, if not all, of its nuclear power stations.

In the light of this new form of terrorism the debate concerning the 'peaceful use of nuclear energy' and the threat resulting from a war-like conflict gains relevance. Up to now it has been, and still is, largely avoided in the nuclear community. Reactors in the international conflict areas such as the Korean Peninsula, Taiwan, Iran, India or Pakistan give rise to an unintentional but deadly side-effect. Once they are in operation a potential aggressor no longer needs atomic bombs in order to devastate the country in question with radioactivity – air force or artillery would suffice. In view of such perspectives anyone resorting to the term 'security of supply' with regard to nuclear energy is obviously not thinking far enough ahead. There is no other technology whereby a single event can cause the collapse of one whole pillar of the energy supply. A national economy relying on technology of this kind is anything but secure in its energy supply. In the case of war it is more susceptible to conventional attacks than a national economy without this technology.

In 1985 the German physicist and philosopher Carl Friedrich von Weizsäcker justified his conversion from supporter to an opponent of nuclear energy saying that: "The worldwide

implementation of nuclear energy implicitly calls for a global radical change in the political structures of all present cultures. It requires the overturning of the political institution of war that has existed at least since the beginning of the civilised world (cf. Meyer-Abich/Schefold 1986)." But in summing up his thoughts von Weizsäcker pointed out that politically and culturally secured world peace was nowhere in sight. In times of 'asymmetric violence', in which highly ideologised extremists prepare themselves for a war against powerful industrialised countries or even the all-embracing 'clash of civilisations', the prospect of lasting peace is far more remote than in 1985 when von Weizsäcker, still haunted by the old block confrontation, formulated his views.

Incidentally, the menace arising from power stations as a result of war-like conflicts is not only a theoretical consideration. In the Balkan conflict at the beginning of the 1990s the Slovenian nuclear power plant, Krško, often found itself exposed to the threat of air attacks. In order to demonstrate the possibility of such an escalation Yugoslavian bombers flew over the plant. It can only remain a matter of speculation whether in 1981 Israel would have refrained from an air attack on the construction site of the Iraki research reactor Osirak, if the 40 megawatt reactor had already been in operation. The attack was seen as a preventative strike against Saddam Hussein's attempt to be the first to build the 'Islamic bomb'. American bombers renewed their attacks on the reactor site during the Gulf War of 1991. In retaliation Saddam Hussein aimed his scud rockets at the Israeli atomic centre of Dimona. Last but not least, more and more reports relating to the conflict with the Mullah regime in Tehran are circulating about a planned Israeli air strike on supposedly secret nuclear plants in Iran.

Deadly Siamese twins: the civil and military use of atomic energy

Since the birth of the idea to use atomic powers for the controlled production of energy, their military misuse has been on the agenda. This came as no surprise to anyone. After all the US bombing of Hiroshima and Nagasaki in August 1945 had clearly demonstrated the infernal potential of nuclear energy to the world. US President Dwight D. Eisenhower's programme 'Atoms for Peace' announced in 1953 was intended as a kind of starting shot for the 'peaceful use of nuclear energy'. This approach was born of necessity and concern since by generously revealing its then largely exclusive and secret know-how about nuclear fission, the USA wanted to prevent more and more countries embarking on their own atomic weapons programmes. The deal that the President of the USA, which had conclusively risen to the status of superpower as a result of the bomb, offered the world was conceivably simple. Any interested country was to be able to profit from the peaceful use of nuclear energy as long as it gave up its own atomic weapons ambitions in return. In this way he hoped to put a stop to a development whereby a few years after the Second World War, along with the USA, the Soviet Union, the UK, France and China had become atomic weapons states. Other countries, among which even those that have always been regarded as downright peace-loving – such as Sweden or Switzerland – were working more or less intensively, but at all events under the utmost secrecy, on the development of the ultimate weapon. Even the Federal Republic of Germany, itself not a sovereign state from the end of Second World War until 1955, displayed corresponding ambitions in the era of the 'Atomic Minister' Franz Josef Strauß.

The Non-Proliferation Treaty which finally came into force in 1970 was – like the International Atomic Energy Agency in Vienna – a result of the Eisenhower initiative. The task of the Vienna atomic agency, which had been founded as early as 1957, was on the one hand to encourage the production of nuclear energy and to promote it worldwide and on the other hand to prevent the development of the atomic bomb in an ever-increasing number of countries. More than half a century after its creation the record of the IAEA is as ambivalent as its original purpose. By monitoring civil atomic plants and their use of fissile materials it has dramatically succeeded in decelerating the proliferation of the bomb. For this, the Vienna agency together with its then

director, Mohammed el-Baradei, received the Nobel Peace Prize in 2005. However, it has certainly not prevented the spread of the bomb. By the end of the Cold War three further atomic weapons countries, namely Israel, India and South Africa, had already joined the five 'official' ones. When it renounced its Apartheid system at the beginning of the 1990s South Africa destroyed its nuclear arsenals. After the Gulf War of 1991 inspectors discovered a secret atomic weapons programme in Saddam Hussein's Iraq that was highly advanced in spite of meticulous monitoring on the part of the IAEA. In 1998 India and Pakistan, which like Israel had always refused to sign up to the treaty, shocked the world with nuclear weapons tests. Five years later North Korea turned its back on the Non-Proliferation Treaty and declared itself a nuclear weapons state.

All these threatening developments are rooted in a fundamental problem of nuclear energy: even with the best intentions and despite the use of the most modern monitoring technology, there can be no fine distinction between its civil and military use. In particular the nuclear fuel and fissile material cycles involve a largely identical process whether for peaceful or non-peaceful use. Technology and know-how are frequently open to civil as well as military use – 'dual use' – with a fatal consequence. Every country that can fully handle the civil nuclear technology as promoted by the IAEA or the European Atomic Community (Euratom) can build the bomb sooner or later. Again and again since the beginning of the nuclear age, ambitious and unscrupulous powers have secretly gone down the military side road at the same time as pursuing the civil nuclear programme. Iran is today and has been suspected of doing this for years. The conversion of civil components of the nuclear fuel cycle into military ones can be carried out through secret parallel programmes subsidised by the respective governments. Or it can take place by secretly diverting civil fissile materials and thus avoiding national and international controls. The theft of such materials, military relevant technology or the relevant know-how is also to be feared.

At the beginning of 2010 in the Near and Middle East 15 new nuclear power stations were planned in Iran, Turkey, Egypt, Saudi-Arabia, Jordan, Libya, Algeria, Tunisia, Morocco and the United Arab Emirates. One does not have to be a prophet to foresee that not all of these projects will be realised. But if the world were a safer place, would even half of them be built? Indisputably, the more civil nuclear technology expands throughout the 30 countries which use it commercially at the moment, the greater the effort becomes to curb military proliferation. In the case of a new nuclear energy boom – similar to that of the 1970s – resulting in 50, 60 or even more countries having access to nuclear fission technology, it would pose the IAEA, already overburdened in the past and chronically underfunded, with insoluble problems. Furthermore, there is a new form of danger in the shape of terrorists who would not even shrink from detonating a 'dirty bomb'. The detonation of a conventional explosive device containing radioactive material of civil origin would not only claim numerous victims and dramatically increase fear and insecurity in the countries which are potential targets for terrorists but would also render the site of the explosion uninhabitable.

Third Myth: Atomic Waste? No Problem!

The comforting concept of the nuclear 'fuel cycle' is just one of those astonishing neologisms of the nuclear industry that have comprehensively established themselves in spite of the fact that reality continually proves them wrong. The myth of the nuclear cycle originated from the early dream of nuclear technologists that after having started with commercial uranium reactors it would be possible for reprocessing plants to separate the fissionable element plutonium produced in its core and then, in fast breeder reactors, continually produce plutonium (Pu-239) out of non-fissionable uranium (U-238) for further fast breeder reactors – like a perpetual motion machine. In this way a gigantic

industrial cycle was to be created with more than a thousand fast breeder reactors and dozens of reprocessing plants all over the world, on a civil and industrial scale that has so far only been realised in La Hague in France and Sellafield in England. In Germany, alone nuclear strategists in the middle of the 1960s were counting on an arsenal of breeders by the end of the century capable of generating an aggregate output of 80,000 megawatts. For comparison: the conventional pressurised water and boiling water reactors in operation in Germany today produce about 20,000 megawatts. However the plutonium path of nuclear technology, which the energy scientist Klaus Traube – himself initially head of the German breeder project in the Lower Rhine town of Kalkar – had called the "salvation utopia of the 1950s" (Traube 1984), has turned out to be perhaps the greatest fiasco in economic history. Over-priced, technologically ill-conceived and even more controversial in safety terms than conventional nuclear power stations and, moreover, particularly susceptible to military misappropriation, breeder technology has not established itself anywhere in the world. Russia is alone in still operating a breeder reactor dating back to the early development stages. Japan (whose demonstration breeder in Monju has been shut down since a serious sodium fire in 1995) and India are still officially going down this route.

Without the prospect of the breeder option the original main motive for separating plutonium for civil use in reprocessing plants actually no longer exists. Nevertheless, along with France, the UK and Russia, Japan and India operate smaller reprocessing plants with the later stated aim of re-using the plutonium produced there in the form of so-called uranium-plutonium mixed oxide (MOX) fuel elements in their conventional light water reactors. Besides plutonium and uranium, reprocessing plants, when they are not out of operation owing to technical problems, above all produce horrendous costs and create, moreover, highly radioactive nuclear waste that has to be disposed of. And the surrounding area is also exposed to levels of radiation exceeding that of a light water reactor several tens of thousands of times over. In addition, reprocessing necessitates the frequent, precarious transportation of highly radioactive materials which also lend themselves in part to military or terrorist misappropriation.

As only a comparatively small part of the highly radioactive nuclear waste produced in commercial power plants worldwide is ever reprocessed and burnt out MOX fuel elements are generally not re-cycled again, the nuclear fuel cycle remains in name only. In the real world this circle is open. Besides electricity, nuclear power stations produce above all high, medium and low-grade radioactive waste which is moreover highly toxic. It has to be securely and ultimately disposed of for immense periods of time. How long, is determined by the natural half-life times of the radionuclides which differ enormously: the plutonium isotope Pu-239 loses its radioactivity only after 24,110 years, the Cobalt isotope Co- 60 already after 5.3 days.

There is no place for permanent disposal – anywhere

More than half a century after the start of nuclear energy production there is not a single approved and operational disposal site for highly radioactive waste in the world – a situation which popularised the image of the nuclear aircraft that took off without any thought of where it was going to land. In some countries – e.g. France, the USA, Japan or South Africa – comparatively short-lived and medium or low-grade radioactive waste is deposited in special containers near the surface. Germany has chosen the former iron ore mine shaft, Konrad, in Salzgitter in lower Saxony for the deep disposal of non-heat producing waste from nuclear plants as well as from research reactors and medical usage. The former mine is the first and only approved permanent nuclear waste facility in Germany and is being prepared for storage at the present time. It is due to start operating in 2014.

The comment made in 1969 by the previously quoted Carl Friedrich von Weizsäcker shows how casually the problem of nuclear waste was initially approached. At the time the physicist and

philosopher remarked on the disposal of nuclear waste: “It is no problem at all. I have been told that all the nuclear waste present in Germany in the year 2000 will fit into a box, a cube with a side length of 20 metres. If you seal and lock it properly and put it down a mine shaft, we can hope the problem has been solved.” (cf. Fischer et al. 1989)

However, from the outset there were other, more reflective, opinions even if they were seldom heard in public. Following a ministerial meeting to discuss the draft of the Atomic Bill, a Bonn ministerial official commented soberly: “The harmless disposal of radioactive waste is a problem that has to be solved before we can entertain the idea of building a reactor in a densely populated Germany.” (cf. Möller 2009). That was in February 1955. Meanwhile in Germany 19 power and prototype reactors have been shut down again without the subject of “the harmless disposal of radioactive waste” coming up on the horizon. In the end it is rather a philosophical question whether radioactive waste can be prevented from penetrating the biosphere at all for hundreds of thousands or even millions of years. It exceeds the bounds of human imagination. The age of the pyramids was only 5,000 years ago. But the highly radioactive waste produced in German nuclear power plants in 2010 will have to be in secure storage even in the year 10010 or the year 100010. However, there is no choice: nuclear waste exists and as there can be no absolute certainty in this matter we have to search for and find the best technical solution based on today’s knowledge.

The largest nuclear energy countries are only gradually and reluctantly coming to the realisation that the choice of a permanent disposal site is not simply a technical or scientific problem. None of the national procedures for choosing a site, embarked upon for the most part in the 1970s, have so far led to an approved permanent disposal site. This is due to the fact that societal resistance, democratic participation and transparency in the choice of a site were ignored or denied for far too long. When choosing a suitable disposal site usually irrelevant and politically strategic considerations played a decisive part. In Germany, in an attempt to learn from these mistakes, a selection procedure consisting of several stages with the continuous participation of the public was developed and formulated. It now seems as unlikely as ever that after years of intensive debate the concept finally agreed on in 2002 by scientists who were supporters as well as opponents of nuclear energy actually came to fruition. The German Christian-Democrats (CDU/CSU) and Liberals (FDP)[2] coalition government elected in the autumn of 2009 has no intention of getting involved again in the search for disposal sites and is sticking to the site in Salzstock von Gorleben that has been in preparation since the 1970s. This is in spite of grave doubts regarding the geological suitability particularly of the overlying rock and evidence from contemporary witnesses and documents discovered in recent years reinforcing the suspicion that in deciding the site in the 1970s political considerations had played a large, if not a decisive, role – rather than scientific findings into the suitability of Salzstock. Anyone looking for “the best technological solution based on today’s knowledge” for a permanent disposal of radioactive waste obviously has to weigh up the alternatives. However, that has never happened and could result in the courts deciding against Gorleben, should politicians cling to the controversial site. Decades would have been lost and the search would have to begin again. Whether the ‘shut your eyes and hope for the best’ strategy pursued by the CDU/CSU and FDP coalition in Germany since 2009 will actually lead to a site being approved is therefore questionable. What is not questionable is the effect the aggressive attempt to establish Gorleben as a permanent disposal site and at the same time extend the life spans of reactors will have: namely the revival of the fundamental conflicts surrounding nuclear energy in Germany.

[2]Conservative CDU and pro-business FDP coalition

At the beginning of 2010 a legal report from the German Environmental Aid Association came to the conclusion that extending the life spans of nuclear power stations as planned by the Federal Republic of Germany violated the constitution since the question of disposal remained unresolved (Ziehm 2010).

That is all the more probable because the joint attempt by the German state and the nuclear energy industry to dispose of low and medium grade radioactive nuclear waste in the abandoned salt mine at Salzberg Asse 11, near Saltzgitter, threatens to end in a monumental disaster after only 30 years. If over a period of ten or more years, as suggested at the beginning of 2010 by the Federal Office for Radiation Protection (BfS), nearly 126,000 containers of radioactive waste, salvaged from the mine because it is in danger of being flooded, have to be re-packed, stored provisionally elsewhere and at some stage buried underground in a more suitable place, this transaction will symbolise the failure of an energy policy costing billions. It is likely that for the first time ever TV pictures will be broadcast into every living room for a whole decade showing the repercussions of nuclear technology and the legacy of burdens bestowed by a generation of parents on their children and grandchildren for which they themselves bear no responsibility. On October 16, 2009 after the decision on the excavation of the containers the German daily newspaper *Frankfurter Allgemeiner Zeitung* was forced to observe: "This is certainly another nail in the coffin of nuclear energy in Germany". According to Paragraph 9a of the Atomic Law those operating nuclear power stations are "liable for the orderly disposal of the resulting radioactive waste". The law has been unmistakably clear on this for more than half a century. But how, where and, above all, when the requirements of the law are to be fulfilled is as unclear in 2010 as it was in 1960. Nevertheless, in this respect Germany cannot simply be looked upon as an irritating exception – it is exactly the opposite, since the situation is the same in nearly all countries where nuclear energy is used commercially. At the present time it is only in Finland, a country that is home to only 4 of the 436 atomic power stations operating worldwide, that plans for a permanent disposal site are well advanced. The disposal site in granite rock near Olkiluoto on the west coast of Finland which is nearing completion is fortunate in enjoying a high level of acceptance by the local and regional population. A nuclear power plant operating in the same place for many years without any major incidents together with a disposal site for low and medium grade radioactive waste have allayed the fears of the majority of the residents. The permanent disposal site for highly radioactive waste is due to start operation in 2020.

However, in none of the countries of the world with a far larger proportion of nuclear power stations in operation is a permanent disposal site in prospect. This is also true of the USA where 104 reactors supply about 19% of the electricity demand. After decades of bitter conflict the plans for a permanent disposal site in the Yucca mountains in the US state of Nevada were put on hold by the Obama administration at the beginning of 2009 due to continued doubts regarding long-term security and because the size of the storage site is probably insufficient to accommodate the highly radioactive waste which has built up over half a century in the USA and which will continue to do so in the foreseeable future.

The Fourth Myth: There is Enough Uranium Fuel

The so-called nuclear fuel cycle is not broken in only one place. From the beginning, it has proved to be problematic even at its starting point. The mining of uranium which provides the fissile material for both the atom bomb and for civil use in nuclear power stations claimed an enormous number of victims especially in the early years of the atomic age. Large quantities of naturally radioactive nuclides, previously safely bound under the surface of the earth escaped into the

biosphere. By continuing or even expanding the use of nuclear energy the health and ecological toll of mining uranium will in all probability increase considerably.

The rush for heavy metal uranium – in itself not unusually rare but only found in sufficient concentrations to be worth mining in very few places – began shortly after the Second World War. The horrendous effect of the US bombing of Japan had not actually done anything to curb the endeavours of the Allies to safeguard their access to this strategic resource but had in fact fuelled them further. Enormous efforts were made to expand and secure their access to the uranium resources. The effects on the health of the workers played a secondary role. The USA exploited mines in their own country and in neighbouring Canada; the Soviet Union intensified uranium mining in East Germany, Czechoslovakia, Hungary and Bulgaria. Thousands of miners suffered an agonising death from lung cancer after many years of hard labour in badly ventilated tunnels, polluted with dust and the radioactive gas, radon. Workers in the East German mine, 'Wismut', which at times employed more than 100,000 people, were particularly affected. Since the concentrations of uranium in the mines usually amounted to as little as 10%, it resulted in large amounts of radioactively contaminated debris. This led to permanent serious radiological damage not only to the miners themselves but also to the surrounding areas and the people living there.

The situation improved for a time with the onset of nuclear energy production in the 1970s. From then on, governments were not the only buyers of fissile material. A private market for uranium established itself so that the exceptional military strategic position of uranium was no longer able to justify the particularly harsh mining conditions. The situation changed radically again at the end of the Cold War. The military demand for uranium decreased enormously. Superfluous stocks in the USA and the former Soviet Union were channelled into the civil fissile material market. Moreover, as a result of the progress made in nuclear disarmament, large amounts of weapons-grade uranium with a high proportion of fissile material soon became available from the mothballed Soviet and American nuclear weapons as well. The consequence was the most comprehensive programme ever for the conversion of weapons of war for use in the civil economic cycle. The explosive bomb-making material is 'diluted' on a grand scale with the natural or depleted uranium (Uranium 238 – from which the fissionable isotope Uranium 235 had been extracted) and then used as fuel in conventional nuclear power stations. This exceptional situation in the uranium market led to a massive collapse in the world market price for reactor uranium. The only storage sites to have survived are those with comparatively high concentrations of uranium. By 2010 nearly half of the applied uranium in nuclear power stations around the world no longer came from enriched "fresh" uranium but rather from the military legacy of 'warring' Superpowers.

The military uranium stocks from the Cold War era are gradually running out. As a result the price of uranium has already increased significantly – a trend that is likely to continue. In the event of existing power stations continuing to operate or the expansion of the global nuclear arsenal, mines that were temporarily closed would have to be re-opened and new, ever increasingly less productive ones developed – in other words, deposit sites which tend to produce less and less uranium and more and more precarious debris containing an above average proportion of radioactive isotopes. This poses a huge problem for the environment and the health of the people living in the affected areas.

The anticipated shortage of the supply of uranium is intensifying as a result of a massive imbalance between the countries producing it and those consuming it. Canada and South Africa are the only two countries in the world using nuclear power for electricity production that are not dependent on importing uranium. The most important nuclear power nations either produce virtually no uranium of their own (France, Japan, Germany, South Korea, Great Britain, Sweden and Spain) or their capacity is insufficient for the long-term operation of their reactors (USA and Russia). Hardly anywhere in the world is nuclear power a domestic energy source as far as the fuel supply is

concerned. Russia in particular could soon find itself faced with a serious crisis in its uranium supply – a situation that could have an effect on the operators of nuclear plants in the EU who import about a third of their fuel from Russia. As well as Russia, China and India could be faced with a shortage if they carry out their declared intention to expand their arsenal of reactors.

After all this one thing is clear: neither the issues of supply nor those relating to waste disposal in the case of the 436 nuclear power stations operating in the world at the beginning of 2010 can be considered to have found a long-term solution. The construction of new reactors that has been the subject of debate in many countries and that some governments have actually pressed ahead with would only exacerbate the problem. In view of the short supply of uranium and for the most part the disproportionately high cost of extracting it, a determined global strategy of expansion would soon lead to the start of a plutonium economy once and for all. This would involve the widespread reprocessing of spent fuel and fast breeder reactors becoming standard. Such a trend would exponentiate the nuclear risks of the present day. It would eventually multiply the amount of radioactive waste to be disposed of and the search for permanent disposal sites would have to be extended to more places with an overall correspondingly larger disposal capacity.

Fifth Myth: Nuclear Energy Benefits Climate Protection

The scientific findings that have now gained full acceptance as well as the evidence gathered from around the world no longer leave any real doubt as to the reality of climate change. In order to just about be able to achieve the aim aspired to by the world community to limit global warming to 2 degrees Celsius higher than that of pre-industrial times, substantial reductions of greenhouse gas emissions are compulsory. Climate experts in industrial nations are calling for carbon dioxide (CO2) reductions of 80 to 95% by the middle of this century. In highly populated, rapidly developing emerging countries the massive increase in emissions has to be moderated, envisaged to come to a standstill and eventually reduced, too. If mankind is to survive, countries such as China, India, Indonesia and Brazil can no longer simply imitate the affluence model of the industrial Northern countries with their high energy consumption, based mainly on the burning of fossil raw materials – and these latter countries in particular cannot continue to carry on as before.

It can come as no surprise to anyone that the supporters of nuclear energy are putting nuclear technology forward as part of the solution in this precarious situation. The trigger for the conflict that has flared up again in many industrial nations as well as in the emerging and developing nations is its alleged potential for reducing global greenhouse gas emissions. It is this prospect that encourages the supporters to press for a ‘renaissance of nuclear energy’ after decades of stagnation and the decline of nuclear technology. In operation, nuclear power stations produce practically no CO2. Supporters of nuclear energy therefore see them as an absolutely essential cornerstone in the stemming of global warming. “An energy agenda, if it is going to last for more than a day,” as Wulf Bernotat, the director of the Düsseldorf energy company E.on, pondered many years ago, “has to deal with the trade-off between abandoning nuclear power and the drastic reduction of CO2 emissions. You cannot achieve both at the same time. That is just wishful thinking” (Berliner Zeitung, 3 December 2005). By saying so, like many other protagonists of the traditional energy industry, the director of the largest private energy company in the world is using the most important argument for continuing nuclear energy production. It goes like this: climate protection is condemned to failure without the use of nuclear energy. “Despised climate activists” is the slogan used in the most extensive advertising campaign by the German nuclear lobby in its history. We can still remember the delightful pictures – right in the background, the nuclear power station at

Brunsbüttel bathed in soft sunlight while in the foreground sheep are grazing peacefully on the banks of the Elbe. The text reads: “This climate activist is fighting 24 hours a day for the implementation of the Kyoto protocol.” In reality, since the summer of 2007 the old reactor had been fighting with technological problems and with doubts as to its safety for over 2 years – and did not produce a single kilowatt hour of electricity.

It is only gradually that the public is becoming aware of how fundamentally flawed this propaganda that portrays nuclear energy as the saviour of the climate is. Nuclear energy lacks the potential to make any noticeable contribution to solving the problem on a global scale. In fact, its importance for the global electricity supply – in spite of any talk of renaissance – is predicted to decrease dramatically in the coming decades. This was pointed out recently by the Swiss company, Basler Prognos AG, in the autumn of 2009. In an analysis for the Federal Office for Radiation Protection the futurologists delivered the following prognosis bringing the nuclear industry down to earth: the nuclear contribution to the global electricity demand will shrink from 14.8% in 2006 to 9.1% by 2020 and to only 7.1% by the year 2030 (Prognos AG 2009). We will come back to this later.

How nuclear energy obstructs sustainable climate protection

With just these few findings it is quite clear that from a world perspective nuclear energy production simply lacks the scale to be part of the solution to the climate problem. On the other hand it is even becoming part of the problem owing to the imminent re-structuring of the global energy system and this is linked to the fact that more and more countries will be pressing ahead with changes to an energy system based on sustainable sources: wind, water, solar, bio and geo-thermal energy. New nuclear power stations simply cannot compete in such a world. But above all they act as obstacles on the road to a comprehensive solution to the climate problem.

Ironically enough it was E.on of all companies, with Wulf Bernotat at its head, that provided the crucial lead in clarifying the situation – even if this was not intended. At the beginning of 2009 the British government set up a hearing to consider their strategy on renewable energies that it had already introduced. In order to implement the corresponding EU targets, the aim of the plan is to increase the proportion of green electricity to almost a third of the British electricity supply for the time being. This proportion is then expected to increase further. According to the documents of the hearing, both E.on and EDF (Electricité de France), the French state-owned company that is intent on promoting nuclear energy, spoke out at the hearing (UK Department for Business, Innovation and Skills 2008). Both sounded an alarm. E.on warned about ‘endlessly’ promoting renewable energy. Otherwise the company would not be in a position to implement its plans for the construction of new nuclear power stations on the island. In their statement to the British government the E.on lobbyists suggest limiting the proportion of green electricity to a maximum of one third – a value that, according to the plans of the black/yellow coalition government, is supposed to be achieved in Germany as early as 2020. EDF points out explicitly that a higher proportion of green electricity than 25% would cast doubt on its own ambitions for new nuclear power plants in the UK.

In Germany, on the contrary, E.on and the likes categorically dispute the existence of a ‘conflict of systems’ between the erratic supply of electricity from wind and solar energy on the one hand and nuclear energy on the other. The motive for this two-faced argument is obvious: what would prevent the construction of new reactors in the UK apparently does not challenge the life span extensions of ageing reactors that the companies are striving for in Germany, where already 16% of its electricity was produced regeneratively in 2009. However, it is undisputed that in the future, for economic and security reasons, nuclear power stations will not be able to adjust to the ever increasing erratic green electricity supply and the electricity demand that is subject to high levels of fluctuation as well.

Month after month nuclear power stations deliver their maximum output. That is what they were built for and that is why they are so lucrative for their operators.

Admittedly, the output of some reactors can be regulated up and down today when they are operating in their upper performance range. However, such an unusual procedure affects the economic viability of power plants because in their load dependent mode of operation they produce less energy and therefore sell less. It is also detrimental to safety because any changes in the reactor's output involves additional mechanical, thermal and chemical pressures on important reactor components. This is precisely what the French state-owned company, EDF, confirms in its aforementioned statement regarding the renewable energy strategy of the British government. Using the European Water Pressure reactor as an example, the EDF spokesmen point out in detail why green energy should provide no more than 25% of the British electricity production in the future. The limitations of the power control system in nuclear power stations are the reasons given for this. Even modern reactors like an EPR can only keep pace with the natural fluctuations of energy from renewable energy sources as long as their contribution to the electricity supply is not very large. In a supply system orientated towards durability and climate protection, nuclear and green energy technology therefore obstruct each other.

However, in 2010 the UK is a long way from this situation as green energy only makes up a small percentage of its energy needs. It is different in Germany where the consequences of this conflict of systems are already noticeable today – and they intensify with every year that passes. The time will come when the limited ability of nuclear power plants to control their output will not be enough to enable them to adjust at any given time to the increasing amounts of energy going to the grid from wind and solar power. The effects of this phenomenon have been tangibly felt – for example, in the Leipzig energy exchange, EEX, where there have been more and more cases of negative electricity prices. That means that the energy supply companies make a loss on the electricity they produce and supply to the grid. This situation that in the first instance seems absurd occurs when a strong wind is blowing over Germany and, at the same time, the demand for electricity is low – usually at weekends or on public holidays as, for example, at Christmas in 2009. For a whole 11 hours the spot market price was below nil or at times down to as far as minus 120 Euros per megawatt hour. On December 26, throughout the course of the whole day the average price settled down to under minus 35 Euros per megawatt hour. For the large power plant operators who in spite of this situation still supply electricity to the grid and trade it on the market, this soon adds up to six or seven figure sums. However, so far it seems more economical for energy suppliers to supply energy that is not actually needed at a loss for a few hours from their so-called base load power stations than to reduce the output of their gigantic power plants and soon after raise it again.

The competition between nuclear energy and renewable energy is intensifying

It is indisputable that we are threatened with an explosive conflict. The production of electricity from renewable energy plants is growing from year to year. More and more frequently, when weather conditions are favourable, they can satisfy an ever increasing proportion of the aggregate electricity demand. And more and more frequently the output of large power stations has to be reduced for hours or days – in any case, as long as the grid gives priority to green electricity. What began as an unpleasant Christmas present for the companies at the end of 2009 will gradually become an everyday phenomenon and threaten their dominance. By 2020 the proportion of electricity supplied by green energy is due to double from the 16% in 2009. The German Federal Association of Renewable Energies (BEE) even considers the possibility of it tripling. A simulation of the electricity supply in Germany drawn up by the Fraunhofer Institute for Wind Energy and Energy Systems Technology (IWES) in Kassel comes to the conclusion on the basis of this prognosis that there will be less and less room in our future system for large power stations designed for

continuous operation. Against the background of such a perspective, nuclear energy companies will almost be forced to set their lobbying power against the further expansion of renewable energy – from their point of view, the more nuclear power stations still on the grid, the more urgent this will be. In the case of a decision in favour of extending reactor life spans, the next great conflict between the Christian-Democrats and Liberals[3] coalition in Germany and the companies that it has actually promoted is pre-programmed.

It is not only the danger of nuclear power stations that argues against longer reactor life spans but also the fear that their continuing operation will apply the brakes to the restructuring of the energy system in favour of renewable energy and in the end may even bring it to a complete standstill.

Although the 'conflict of systems' between the sun and uranium is a much more burning issue in Germany than in the UK or the US, politicians seem largely unaware of it. This is not so in the case of economists. In the event of a further intensive expansion of renewable energy, the company, Prognos AG, considers it likely that the output of nuclear power stations will have to be reduced more and more often (Prognos AG 2009). The Advisory Council on the Environment (SRU) in Germany presented a paper stating that the continued operation or even expansion of large coal or uranium power stations was not compatible with the simultaneous ever-increasing capacity to generate electricity from renewable sources. "A decision as to the system has to be made. It makes no technical or economic sense to follow both paths at the same time" declared the environmental experts who then went on to argue decidedly for "a decision in favour of the renewable energies system." The companies themselves choose not to comment on these publications, fearing that then the whole absurdity of the debate on extending the life spans of reactors will be exposed. It is even more predictable that they will renew their fight against the statutory prioritisation of renewable energies in the German electricity grid as soon as the question of extending life spans is decided.

This clearly demonstrates that the contest is over the energy system of the future, that is to say the relationship between renewable and nuclear energy, long ceasing to be a question of 'the one as well as the other' as nuclear energy propagandists try to convince us. It is a question of 'either/or'. The 'broad energy mix' that energy companies promote with all their fine words does not work. It cannot work in a system in which renewable energies are supposed to be taking over 'the supply of the majority of our energy'. This, however, is one of the aims of the current coalition in Germany according to its coalition agreement of October 2009. At the same time, it promises energy companies an extension of the life spans of their nuclear power stations. This just will not work. The German Federal government is trying to square the circle.

How Germany can achieve its long-term political aims with regard to energy and climate protection was established by the WWF in its study entitled "Modell Deutschland – Klimaschutz bis 2050" (Germany as a model for climate protection by 2050) (WWF Deutschland 2009). The message of the investigation is that it is only possible if the energy sectors undergo a fundamental restructuring and some sectors – among them the electricity sector – become practically CO2 free within 40 years. A prerequisite is the political will to carry through this structural change against the resistance of the traditional sectors of the economy. Just as in Germany, in the rest of the world it is essentially a question of more efficiency in the supply and use of energy. The precept of efficiency encompasses the building sector, households and, of course, industrial processes and the traffic sector. It is about changing from coal to natural gas and an ever increasing supply from solar, wind, water, biomass and geothermal energies which for the most part will be the only ones remaining in the end. Whether, when and where in the world 'clean-coal' technology – in other words, the separation and

[3] Conservative CDU and pro-business FDP coalition

subsequent storage in deep geological formations of the greenhouse gas, carbon dioxide, resulting from the burning of coal and natural gas – can make a noticeable contribution in the future remains to be seen.

One thing is certain – in this monumental process of change nuclear energy acts as "an obstructive technology" for many reasons, as the Advisory Council on the Environment in Germany commented. This is not only because base load power stations massively obstruct the conversion to renewable energies for electricity production but also because of the existing risks of catastrophe, and the commitment of engineering capacities and financial means which then lack for the restructuring of the energy system. In addition, no other technology is faced with a similar threat: a single serious accident or terrorist attack on a nuclear power station would suffice to put an end to public acceptance of this technology once and for all. Quite probably a large proportion of reactors, at least in democratic countries, would have to be shut down prematurely.

Nuclear climate protection is unrealistic

There is no alternative to a transition from the present energy system based on fossil and nuclear energy sources to a supply completely provided by renewable energy if the long-term international aims pertaining to the climate are to be attained. This transition is achievable with the established technology that is largely available today. The earlier we begin, the less costly it will be. In the end there will be a sustainable energy system that will minimise equally the two huge dangers – that of global climate change and that of catastrophic accidents. The constant claim that there is a conflict of aims between effective climate protection and the rejection of nuclear energy at the same time is an invention on the part of the nuclear energy supporters based on their own self interest. A choice between the devil and Beelzebub is completely unnecessary.

In Germany at least 10 new nuclear power stations would have to be built if the expansion of nuclear energy is to achieve the aim of the Christian-Democrats and Liberals coalition to reduce carbon dioxide by 40% (compared with 1990) by 2020 in the electricity sector. In addition, this would also require the construction of new nuclear power stations to replace the reactors that have been shut down because of their age. As early as 2002, an Enquiry Committee of the German Bundestag determined the implications of a scenario of CO2 reduction by 2050 – achieved mainly on the basis of nuclear power stations. Scientists at the time considered that an arsenal of 60 to 80 new nuclear power stations would be necessary. Compare this with the 17 nuclear power stations operating in Germany in 2010.

In view of such numbers in Germany alone, little imagination is needed to foresee the undesirable worldwide consequences of a nuclear strategy for curtailing the climate impact. To achieve the reduction of carbon dioxide called for by the Intergovernmental Panel on Climate Change (IPCC), thousands of new reactors would have to be built to achieve any noticeable effect. Risks to electricity and of catastrophe would no longer be produced in only 30 but in 50, 60 or even more countries. There would be thousands of potential trouble spots spread across the world and the creation of new targets for military and terrorist attacks in conflict areas. The problems of permanent disposal and the danger of the uncontrolled proliferation of nuclear weapons in all regions of the world would reach a new dimension. And just as importantly, owing to an ensuing uranium shortage, the light water reactors that are common today would very soon have to be replaced everywhere by an even more dangerous and vulnerable plutonium industry with reprocessing and fast breeder reactors. And then finally, enormous financial resources would have to be invested in the expansion of the nuclear infrastructure instead of using it to fight world poverty.

Sixth Myth: We need extended life spans

In Germany since the beginning of the new millennium the question of new nuclear power stations has been broached at best by outsiders who included from time to time a certain Roland Koch or Günther Oettinger (both of the German Christian-Democrats, CDU) until the latter was appointed the EU Energy Commissioner. However, even the CDU grandees were regularly whistled back by their Party colleagues – in December 2008 even by a Federal Party conference. Contrary to the will of the petitioning commission, the majority of the delegates voted against any new reactors being built in Germany. This was just a meaningless decision without any consequences. Because even if an energy company considered applying for planning permission to build a new power station in Germany, it would not be able to do so. "For the construction or operation of power plants for the commercial production of electricity (…) no licences will be granted" – according to Paragraph 7, Section 1 of the Nuclear Withdrawal Act passed by the coalition Social Democrats and Alliance 90/the Greens in Germany in 2002. And even the black/yellow coalition, newly elected in 2009, is sticking – for the time being – to a ban on new nuclear power stations. However, this is of little concern to the nuclear power station operators, E.on, RWE, EnBW (Energie Baden-Württemberg) and Vattenfall Europe as even without the statutory ban, no director of any company in his right mind would embark on such an adventure for the foreseeable future. Instead of fat profits, there would be endless losses.

It is a completely different situation with reactors whose life spans exceed the time limits agreed to with the former red/green coalition government. Nuclear power station operators are arguing in unison about this with such intensity as if the survival of their companies were at stake. But it is not about that at all. And neither is it about other motives which the company directors regularly put forward in support of their arguments: it is not about climate protection, nor the security of supply, nor independence from imported energy and especially not about cheap electricity generated by nuclear power for the consumer. In fact it is about nothing more than vast sums of money and about securing the market position for the dominant operators.

And the amount of money involved has been calculated over and over by scientists ever since the debate on longer life spans – which the passing of the Nuclear Withdrawal Act in 2002 should actually have put an end to – has been the subject of day-to-day politics. Recently even bank analysts are calculating for their potential investors how far the rich rewards of the nuclear power station operators could fall should the Federal Government really reverse its position as it had laid down in the coalition agreement. In the summer of 2009 the German Baden-Württemberg bank, LBBW (Landesbank Baden-Württemberg) calculated the gross surplus profit of these companies at between 38 and over 233 billion Euros – the lower value applies if the lives of all reactors are extended 10 years longer than the proposed 32 years negotiated in the phase-out agreement and, at the same time, the market price for electricity remains overall moderate during that time. The highest value would apply if reactor life spans were extended to 25 years and in the event of high market prices for electricity. With the expectation of a lucrative surplus the value of the four companies would increase enormously. In the case of EnBW it could even double – according to the LBBW bank which therefore considers it meaningful to continue the operation of nuclear power stations.

The enormous sums explain why the company directors are seemingly happy to accept the loss of image undoubtedly associated with their campaign to extend the lives of ageing and accident-prone reactors. The reversal of the nuclear phase-out agreement therefore comes at a cost. For years the nuclear energy opponents and environmental associations have been appealing to customers with

their campaign ‘Nuclear phase-out – do it yourself’ to switch their electricity supply to green energy companies. In this way and as a result of a series of failures in the German nuclear power stations at Brunsbüttel and Krümmel, Vattenfall Europe lost several hundred thousands of customers.

Nuclear energy companies break their promise

“Both sides will play their part in implementing the content of this agreement.” Such were the ceremonious words of the delegates of the largest energy companies in their agreement with the Social Democrats and Alliance 90/the Greens coalition regarding nuclear withdrawal on 14 June 2000. The signatories also included Gerald Hennenhöfer who, as chief representative for economic policy for E.on’s predecessor, Viag, had played a part in negotiating the agreement and since autumn 2009 has now been pushing for a reversal of this agreement as head of the reactor security department in the German Federal Ministry for the Environment. Whether this renewed shift of allegiances on the part of the lawyer already in charge of the reactor department of the Ministry under Angela Merkel up to 1998 is legally admissible is a subject of political conflict. When this agreement was signed, about a year after being initialled, E.on’s chairman, Ulrich Hartmann, commented: “Political compromises are also a question of trust [....]. The agreement is just the first step. The crucial thing is that both sides feel bound to its content and spirit even in the future. We are prepared to do it.” Three years later the then EnBW director, Utz Claassen, categorically endorsed that in no circumstances would there be any change in their position on the question of withdrawal: “I am not speculating about a change in the coalition – my respect for the Chancellor does not allow me to do that.” Before the general election in 2005, Claassen, in a response to a possible reversal of the nuclear consensus, topped it all by affirming that “the industry cannot demand planning security and then question what it itself has negotiated, agreed and signed.” However, ever since polls showed that a nuclear friendly government majority was on the cards, the absolute loyalty of the nuclear energy companies to the agreement ceased to be an issue. Simultaneously E.on, RWE, EnBW and Vattenfall Europe turned their back on the ‘content and spirit’ of the agreement which their directors had ceremoniously signed together with the most important representatives of the government. And Germany knew – years before the financial crisis – that on the management floors of some of the most powerful companies in the country there were businessmen who were not necessarily honourable – because if they were, they would have abided by a contract which no doubt also reflected the wishes of the majority of the population even if it had only been agreed by a handshake.

Following the general election of 2009 the former steel entrepreneur, Jürgen Großmann, who has been at the head of RWE since 2007, announced: “German power stations are safe”, commenting that when they had been in operation for 32 years, at which time German nuclear power stations were supposed to be shut down, they were “in their best years”. He then added in a casual and snappy way that internationally it was rather more common to have “a life span of 50 to 60 years”. The reality is different. The 130 nuclear power stations that had already been permanently shut down worldwide by the end of 2009 had achieved an average life span of about 23 years at the time of their closing whereas in 2010 the average age of those in operation globally is 25 years. There have only been a handful of permanent shut downs after 40 years and there has never been a case of a reactor still in operation after 50 years, let alone 60 (Prognos AG 2009) – so much for accuracy when Jürgen Großman is fighting for his ageing reactors in Biblis.

Why cream off surplus profits?

Representatives of the Christian-Democrats (CDU) and the Liberals (FDP)[4] in Germany have always maintained that they do not intend the beneficiaries of the government's target for extending the life span of nuclear power stations to get it 'for nothing'. They want the extra profits to be used selectively for research or the development of renewable energies, the lowering of electricity prices or other matters that supposedly have popular public support. After the election of their 'dream government' in autumn 2009 reactor operators signalled willingness to compromise. This has not always been the case and the Chancellor and the Minister for the Environment would do well to remember that the companies had previously proved under the Social Democrats and Alliance 90/the Greens coalition incapable of being loyal to an agreement. When the 2005 general election already appeared to have been won by the Christian-Democrats and Liberals coalition just a few days before polling day, the aforementioned Walter Hohlefelder, at that time E.on's chairman and at the same time president of the German Atomic Forum, candidly spoke out on the question of a partial drawing off of the surplus profits resulting from life span extensions: "in terms of regulatory policy the creaming off of profits is totally unacceptable", adding, "what possible interest can we expect commercially active companies to have in extending the life spans of power stations if there is no profit in it for them".

The coalition that was voted into power in 2009 assures us that it only intends to use nuclear power stations for a limited period as a 'bridge' in the transition to the regenerative age. It sounds surprising but this does not distinguish the Christian Democrats and Liberals coalition from its predecessors who, as we know, did not negotiate the immediate withdrawal either but rather a step by step farewell to nuclear technology. A comparison of the expected 'departure' of nuclear power stations following the Nuclear Withdrawal Act with the forecasts regularly drawn up for the Federal Ministry for the Environment concerning the expansion of renewable energies demonstrates that the volume of electricity generated by new wind, solar and bio energy power stations will always more than make up for the loss of nuclear electricity right up until the last nuclear power station is shut down (BMU 2009). According to the Nuclear Withdrawal Act of 2002 the 'bridge function' of nuclear energy in Germany will therefore end between 2020 and 2025. Apart from the companies' interest in profit there is no apparent reason to change anything – not even the alleged gap in the electricity supply that is 'cooked up' from time to time. This will not happen since coal and gas power stations will remain on the grid and supply sufficient power for much longer than the specified term and even some new ones will be constructed.

Withdrawing from nuclear energy the smart way

Increasingly the real challenge is to make green electricity, which is by its nature erratic, available in the right place at the right time throughout the year. This will be possible if the electricity grids are gradually extended and restructured and if the grid coupling points to abroad are strengthened. It will also be necessary for existing electricity storages such as pumped storage hydroelectricity facilities to be adopted and instead of for surplus nuclear energy being used to complement wind generated electricity and for progress to be made in the development of new electricity storage systems (Solar Institute, Jülich, FH Aachen 2009). However, there will be no possible support for this changeover at all – or at best only later – if the 20,000 megawatts generated by nuclear power stations do not go from the grid gradually as planned but block it for decades instead.

In roadworks no one would dream of building a bridge which made getting from A to B longer. It is exactly the same situation with the life span extensions of nuclear power stations. The road to a

[4] Conservative CDU and pro-business Liberals

regenerative energy age would be longer and Germany, instead of being in the vanguard of energy change, would be lagging behind within a few years.

Seventh Myth: Nuclear Energy is Experiencing a Renaissance

Today nuclear power stations play an important part to a greater or lesser degree in the electricity supply of the 30 countries where they are operating commercially. In this way they form in part the basis of the economy in these countries. Therefore, it is above all the respective energy industry that up to now determines the future – unless outside strategic or military strategic interests have a part to play. And this industry under normal circumstances takes into consideration sober economic factors. The question of whether electricity generated by nuclear power means a licence to print money or is more like a bottomless pit can be answered depending on the circumstances: if the reactor has reliably been producing energy for 20 years and there is no reason to suppose it will not continue to do so, then the former is more likely –as long as no catastrophe that is potentially inherent in any power station actually happens. But if the power station first has to be built and moreover is the first in a new series, investors would be well advised to steer clear of any such project, unless they succeeded in passing on the incalculable costs to a third party. This would be the tax payer or the electricity customer. The same principle applies all over the world – even if it is the government itself that builds the reactor, operates it and later perhaps is responsible for its disposal. Even then the public foots the bill at some stage.

For private investors who have to, or wish to opt for investments in the power plant industry today, nuclear power stations are quite obviously not their first choice. Even the empirical evidence suggests this. According to the statistics of the International Atomic Energy Agency in Vienna at the beginning of 2010 there were 436 nuclear reactors in operation worldwide with a net electricity capacity of around 370,000 megawatts. The zenith was passed in 2002 with 444 reactors and since then the number has been gradually and continually decreasing. In the USA alone 104 reactors are on line and since 1973 reactor constructors have not taken on any new orders that were not subsequently cancelled. Nevertheless, since 2007 the USA has been home to the oldest reactor construction site in the world. At that time work began again on Block 2 of the Watts Bar nuclear power station. The reactor is due to be completed by 2012 – 40 years after the foundations were laid. In Western Europe (except France) reactor constructors waited 25 years until 2005 for a new building contract and even now there are only two: one at Olkiluoto in Finland and another one in Flamanville on the French Channel coast.

The European water pressure reactor of the Areva/Siemens consortium turned in record time from being the showcase reactor of the Western nuclear lobby into a nightmare for all stakeholders. The escalation of costs from the initial 3 billion to 5.4 billion Euros (2009) and the delay of three and a half years so far (2012) of the start of operation have resulted in a case being brought before a European Tribunal to settle the dispute between contracting firm and constructor involving billions of Euros. In the case of the second EPR there are also signs of a considerable escalation of costs and delays.

In short, apart from Asian – to be precise, Chinese – state-owned construction sites, the demand for reactor constructors remains disappointingly low. According to the IAEA of the 56 reactors worldwide under construction at the beginning of 2010, two thirds of them are in Asia. China, where 20 new nuclear power stations were being built at the beginning of 2010, has started 15 new projects within two years. In the case of eight of the new reactors under construction, mainly in Russia and

Eastern Europe, 20 years have gone by since they were first started. Under any other circumstances such building sites would be called ruins.

Renewable energy is the new global trend

The analysis prepared by Prognos AG of Basle, for the Federal Office for Radiation Protection has already been mentioned. With reference to the question "a renaissance for nuclear energy?" the experts examined the development that can actually be expected based on the global planning of and experience in nuclear power station construction. The result is as obvious as it is shattering for the nuclear energy lobby: there will be no nuclear renaissance by 2030. Quite the contrary, Prognos AG analysts expect the number of nuclear power stations operating worldwide to decrease by almost a quarter by 2020 and by almost 30% by 2030 (Prognos AG 2009). As a result the global volume of electricity produced by nuclear power by 2030 will shrink to less than half of what it was in 2006. Nuclear power as an instrument in the fight against climate change will therefore prove to be an illusion – even more so in view of the explosive rate at which the overall capacity to produce electricity has developed from the start of the millenium to the financial and economic crisis. The available output of power stations has increased rapidly at an annual rate of about 150,000 megawatts. Nuclear energy only amounted to about 2% of this volume, and in the years 2008 and 2009 not even that. During this period two new nuclear plants were put into operation with an output of a good 1000 megawatts, but four reactor blocks which had an output of just under 3,000 megawatts were shut down. In these two years the developing wind farm industry provided an additional volume of nearly 60,000 megawatts in spite of the global economic and financial crisis.

Although the role of nuclear energy is therefore proving marginal in the light of the gigantic global increase in power plant capacity, reactor operators are nevertheless fighting with determination to extend the operating life span of existing reactors to well over the 25 to 30 years that was originally estimated by their constructors. The optimistic scenarios depicted by the IAEA expect an average life span of 45 years for the existing generation of reactors. In the last few years US authorities have granted life spans of 60 years for more than half of all the 104 nuclear reactors. It is expected that similar applications will be accepted for most of the remaining reactors. Meanwhile the industry is discussing life spans of 80 years. The actual average age of US reactors in 2010 is 30 years.

In the absence of any serious accidents to upset the balance and barring any expensive repairs and long periods of shut down or any necessary replacements of central components (e.g. the steam generator) due to wear and tear or corrosion, then ageing reactors of the 1000 megawatt capacity category that were written off can continue producing electricity inexpensively without any competition. Prolonging the life spans is putting off the 'bitter end' of the nuclear energy industry – that is to say the de-commissioning and dismantling of the large reactors and the inevitable costs running into billions that this would involve. As fuel costs are a smaller part of the equation in the operation of nuclear power plants, companies everywhere are counting on additional yields worth billions.

However, all this haggling about life spans has nothing to do with a possible renaissance of nuclear energy. If anything, the opposite is true - the calls for 'extra time' clearly indicate that electricity suppliers shy away from investments in new nuclear power stations out of economic considerations, preferring to make a quick profit from old power plants. They do this without considering the increasing susceptibility to failure due to the age of their reactors.
This has in no way halted the continual decline of nuclear energy that has been taking place for decades. In the USA eight years of aggressive pro-nuclear power politics under the Bush administration did not lead to the building of one new project. In Western Europe there are merely two construction sites. Nevertheless, studies have been launched since decades with the purpose of

demonstrating the ability of new nuclear power plants to compete against other technologies for generating electricity. The drawback of these studies is that while at best their authors and sponsors believe the forecasts, potential investors do not. This is the first reason why there is so much uncertainty about the true costs of a new generation of reactors. There are no reliable data on the large overall cost pools, especially the costs relating to construction, financing, disposal and dismantling – due to the fact that nearly all the published estimates are evaluated by analysts with considerable scepticism. And this in turn is due to the fact that all these figures as a rule originate from constructors who want to sell the reactors or from governments, associations or lobby groups intent on gaining public support for the unpopular idea of nuclear energy by promoting at the very least the expectation of low electricity prices.

However, beyond these matters of self interest there are also problems from an objective perspective. Because each new series of reactor constructions so far has had to face the consequences of huge delays, costly compensation for 'teething problems' and lengthy periods of shut down, potential investors regard the ever optimistic prognoses of the builders of new reactors with the utmost discomfort. Their experience: for half a century the nuclear power industry has always been high on promises but short on delivery. In the USA almost half of the orders for over 250 reactors were later cancelled, mainly because the costs of the power plants eventually put into operation had on average more than doubled. The magazine *Forbes* called the collapse of the US nuclear industry in the middle of the 80s "the greatest management catastrophe in economic history". Of the 1000 nuclear power stations the US Atomic Energy Commission (AEC) had expected in the 70s for the turn of the century only about 13% were built. Reactor constructors in Western Europe and in the state economies of Eastern Europe also experienced similar situations.

There can be no reliable predictions as to the performance of a new power plant. This applies even more to the new types of reactors based on mainly untried technology. According to an analysis published in the summer of 2009, the New York rating agency, Moody's, expects electricity supply companies supporting plans for the construction of new nuclear power plants to be routinely downgraded owing to the incalculable risks involved. Whereas new technologies – also those outside the field of power plant technology – normally move relatively continuously and predictably along a 'learning curve' with ever decreasing prices, reactor manufacturers after more than half a century since the start of commercial nuclear fission start over and over again. Therefore in the 1970s and 1980s reactor manufacturers built increasingly bigger reactors in the hope that they would produce, on the whole, cheaper electricity than smaller units. However, switching to economics of scale has not solved the problem. A trend towards less costly reactors has been an unfulfilled promise of reactor manufacturers for decades. Nuclear power remains a high risk technology not only considered from the safety point of view but also from the financial one.

Subsidies to prevent nuclear depression

This applies particularly to the USA. For eight years the Bush administration tried everything to motivate the electricity suppliers in the country into building new reactors. There was talk of up to 300 new nuclear power stations by 2050. However, we are still waiting for the re-birth of the nuclear industry (Squassoni 2009). George W. Bush left his successor Barack Obama a whole range of abundant promises of subsidies for the reluctant electricity suppliers. Government guarantees of over 80% of the total costs for the first of the newly constructed power stations are seen as the most important of these promises. In this way the enormous cost risk, for example due to the regular delays in constructing new nuclear power stations, is passed on from the electricity suppliers and the reactor constructors to the tax payer. Moreover specific tax breaks are intended as a measure to artificially reduce the price of electricity generated by new nuclear power stations. The approvals procedure has been trimmed down. The government undertakes to pay a large proportion of the

costs involved in obtaining grants. In the case of accidents the liability of the companies has been reduced further. Finally even assistance from other countries has been announced. The governments of Japan and France have promised some subsidies for American reactors should investors from both countries participate in the construction.

And yet the US nuclear industry may not see all of this as an all-round worry-free package. On the contrary it immediately declared the wide variety of government and start-up aid as insufficient. To trigger a real renaissance it would additionally be necessary for coal and gas power stations to pay a CO2 tax. As early as 2003 the Massachusetts Institute of Technology (MIT) stated that compared with fossil fuel power stations new nuclear power stations would only become competitive in the event of a CO2 price of 100 dollars per tonne. In 2008 the US Congressional Committee on Science and Technology calculated electricity prices from new nuclear power stations as being higher than those produced by all the other competing low carbon technologies with the exception of solar energy, the price of which is also sinking rapidly (Kaplan 2008). It became clear then at the latest that no subsidies would help without a simultaneous drastic price increase in the fossil fuel competition through CO2 taxes or an emissions trading system. Even in this case, according to the Congressional Committee's analysis, modern gas power stations would still be cheaper. In effect an established technology that has to rely on such a degree of government subsidies in order to be competitive is economically dead on its feet.

However, even Barack Obama and his energy minister Steven Chu have not categorically ruled out the option of nuclear power. The budget for the year 2011 has allowed for credit guarantees amounting to 54 billion dollars for the construction of new reactors – a tribute to the powerful anti-climate protection coalition in the USA. However, no one expects the present administration to continue the pro-nuclear policy as aggressively as George W. Bush's government did. As previously mentioned, for the year 2010 Obama has cancelled all budget resources for the construction of the controversial Yucca Mountain permanent waste disposal project. Even in the event of a policy shift the question of long-term security remains as unresolved as ever. In addition, projections made in 2009 showed that the disposal capacity that had previously been applied for is not even sufficient to deal with the civil nuclear waste that will be produced by 2020 – let alone the radioactive waste from military use and the residue from the operation of nuclear power plants which will continue to accrue after 2020.

Although the US Nuclear Regulatory Committee (NRC) published a list of 17 licence applications for 26 reactor blocks at the beginning of 2009, nobody, not even the American nuclear industry itself, believes that more than a handful of these reactors will be built – if any at all. The insecurity of potential investors is huge, for which the analyses and prognoses coming from Wall Street and other independent experts are also responsible. They are coming up with even more dramatic cost estimates. Recent calculations suggest that average construction costs will be four times higher than the amounts quoted at the beginning of the renaissance discussion. In a cost effectiveness analysis published by Mark Cooper of the Vermont Law School in the summer of 2009 the author concludes that nuclear power is by far the "worst option" as a means of overcoming the challenges of energy supply in the USA (Cooper 2009). According to his analysis, electricity from nuclear reactors would result in prices of 12 to 20 cents per kilowatt hour, whereas investment in energy efficiency and renewable energies would lead to the price of electricity going down to an average of six cents. If by 2050 only 100 new nuclear power plants were built – a number that is just enough to replace the current arsenal of reactors – this would cost the American public over the life span of the reactors the enormous estimated sum of 1.9 to 4.4 trillion dollars more than an energy policy that concentrates on efficiency and renewable energy technology.

At present the Americans can see from the situation in Finland and France, where the only two new reactors in Western Europe have been in construction since 2005 and 2007 respectively, that the sober economic forecasts on the other side of the Atlantic are not the result of the bleak picture painted by notorious nuclear critics. Even the prototype of the European Water Pressure reactor, being developed as the third block of the nuclear power station Olkiluoto, is not a result of the initiative of the Finnish electricity industry but of political pressure. The driving force was the hunger for electricity which had been continually rising for two decades and resulted in a per-head electricity consumption in Finland that was more than double the European average. At the same time politicians became increasingly worried about their electricity supply becoming too dependent on Russian gas and feared that they would not be able to adhere to the national commitment to climate protection as laid out in the Kyoto agreement without any additional nuclear energy. In the end the electricity supplier Teollisuuden Voima Oy (TVO), which is largely publicly owned, awarded the contract to the French-German construction consortium Areva/Siemens.

With the Olkiluoto project the international nuclear community wanted to prove two things. Firstly that a nuclear power plant that two European heavyweights have been planning for over 20 years will actually be realised at some stage. And secondly that nuclear power in a liberalised electricity market can once again be a worthwhile investment. However, from the beginning doubts were justified since the financing of the project was made possible by means of a structure consisting of about 60 participants, mainly electricity suppliers, who, in return for their involvement, signed purchase guarantees of comparatively high prices for the electricity to be produced later in the reactor. In addition, TVO and the producer consortium agreed on a fixed price for the 'ready-for-use' reactor that was supposed to be three billion euros. A contract with such exceptionally attractive terms for the purchaser was possible as Areva/Siemens needed the construction go-ahead at any price. Before they had started digging the foundations it was obvious that the reactor constructor had set a particularly audacious cost framework in order to ensure the triumph of the prototype reactor over fossil fuel power stations and other contenders from the nuclear sector.

At first reactor output was being constantly increased even during the development of the EPR in the 1990s. Size alone was supposed to ensure efficiency and effectiveness. Now the EPR with a projected electricity output of 1,600 megawatts is by far the nuclear power station with the highest capacity in the world. However, the projections that made the reactor in the tendering procedure competitive compared with other, even non-nuclear options, have meanwhile proved even more illusionary than the opponents of nuclear energy themselves had predicted. Along with the construction delay of at least three years, as already mentioned, and a cost explosion of around 80% per cent it is unlikely that other targets will be met either. For example, calculations as to its profitability were based on a 90% availability over the lifetime of the reactor – a value that so far has never even been remotely achieved by a pilot plant – just as the estimated life span of 60 years has not been achieved either. Therefore, long before the completion of the project, it is clear that in the light of the meanwhile applied changes to the parameters Olkiluoto 3 would never have been able to succeed against the non-nuclear alternatives that were competing with it. In other economic sectors there is only one word for this kind of supply formation: dumping.

The financial arrangements of the reactor project which were strongly influenced by the interests of the home countries of the reactor builders, Areva and Siemens, painted a similar picture. The German Bavarian bank, BayernLB (Bayerische Landesbank) with its registered office in Munich and 50 per cent owned by the Free State of Bavaria, where Siemens also has its head office, was a partner of an international consortium which supported the EPR in Finland with a low interest loan (there was talk of an interest rate of 2.6%) to the amount of 1. 95 billion Euros. The French government came to the aid of Areva with an export credit guarantee amounting to 610 million euros via the

Coface agency. It is therefore doubtful whether a decision in favour of investing in the nuclear power plant would ever have been made without financial government support.

This problem did not arise at all in the building of the second EPR on the Normandy coast at Flamanville, France, where the state-owned company Areva is building the pressurised water reactor for the state-owned electricity supplier Électricité de France (EDF). As in Finland, the costs are spiralling out of control. At the beginning of 2010, according to newspaper reports, the building project was two years behind schedule. Numbers three and four in the EPR series are due to be built in China – that is to say under state-controlled economic conditions.

As a result of the enormous uncertainty regarding the building of nuclear power stations electricity suppliers and reactor builders are forced to attract venture capital at correspondingly high prices if they themselves cannot or do not want to advance the money. Next to the building costs capital expenditure is therefore the second great chunk in the financing of a nuclear power station. This problem too has grown more acute with the deregulation of the energy markets in key industrial nations. The financial and banking crisis has further intensified the situation and also because the demand for electricity has decreased considerably as a result of the economic slump.

Everything was better in the past – at least for those who wanted to build, buy or finance nuclear power stations. In times of monopolistic electricity suppliers that were government guaranteed, investors could assume that their capital would always be refunded at the end of the day by the electricity consumers even in the case of a reactor's poor performance. However, in a deregulated energy market the situation is by no means certain any longer. Nuclear energy with its exorbitantly high start-up investment and the timescale for capital repayment lasting decades is not compatible with deregulated markets. Capital costs explode – unless potential financiers do not choose to invest in other technologies that are not beset with these problems. This was the situation in many countries where highly efficient gas power stations experienced a long-lasting boom in the last few decades for the following reasons: the building costs per installed kilowatt hour proved to be decidedly lower, the time between placing the order and the start of operation is short and the plant components are largely made in factories in a production series. And in addition, because the fuel costs of natural gas, which make up a higher proportion of the total costs than uranium does in nuclear power plants, were comparatively low for a long time, nuclear power stations had virtually no chance. In the meantime the price of natural gas may be higher but at the same time great progress is to be expected in the field of renewable energy technology. The point at which it seems overall more profitable for corporate finance to invest in these key technologies of the 21st century instead of in a new series of reactors has already been reached in many places. This will also make it increasingly difficult for potential reactor builders to generate the necessary investment capital.

The end of the nuclear power myth

We have seen that a whole cluster of imponderable factors make nuclear power stations an all-or-nothing gamble for investors. For instance, the time between the investment decision and the start of the commercial operation is nowhere near as long for any other power plant technology. Prognos AG calculates a worldwide average of eight years' construction time alone. There can be enormous planning problems and delays in obtaining the permit owing to the fact that the authorities responsible are in the public eye and proceed with exceeding meticulousness. In addition, new security relevant findings make a revision of the approvals procedure necessary. Or it may well be that a court decides in favour of the objections raised by nuclear power protestors. For example, the go-ahead was given for what is so far the last British reactor, Sizewell B, in 1979 but the commercial operation started 16 years later.

In contrast to most of the other power station technologies, nuclear power stations incur high costs for decades even after being put into operation. These include the disposal of radioactive waste, the surveillance of reactors that have been shut down and finally the dismantling of the reactors after a 'fall time' which can vary in length. The financial means to do all this have to be earned during the operating time and set aside for a much later use. The costs incurred for this and for the insurance in case of possible accidents differ from country to country. Estimating these costs, in this case, is especially difficult due to the fact that the normal deduction of accrued interest over the time period expected does not work. At a discount rate of 15%, costs which become payable in 15 years or later are to be ignored. As these costs are guaranteed to be incurred sooner or later they represent another source of uncertainty regarding the financing of reactors and the calculation of electricity production costs.

That the number of new reactor projects has nevertheless increased slightly in the last few years in spite of all these difficulties can be attributed, as already mentioned, to Asian countries alone and especially China where there were 20 construction sites at the beginning of 2010. As a matter of fact, the building times of six years in China are well under the global average. However, even if China actually brings the 50 to 60 Reactor blocks planned by 2030 on line, these power plants once completed will hardly satisfy more than 4% of the Chinese demand for electricity.

In contrast the order books of the few remaining Western reactor builders remain relatively empty for the time being. This is also due to the fact that China focuses ever more strongly on its own technology. Beyond the debate about extending the life spans of reactors, nothing much is happening apart from in Asia. There is no evidence of any actual new projects in the majority of the countries involved in spite of all the hype in the newspapers. As such, it is the politicians and publicists, even more so than the reactor builders or electricity suppliers, who press on with the debate on the renaissance of nuclear energy. They believe that with nuclear energy and by maintaining the traditional structures of the energy economy they will better be able to comply with climate protection obligations or avoid electricity shortfalls in the short term. This constellation is not without its consequences since the more intensively the politicians and the public push for a resurrection of nuclear technology the more uninhibited potential investors are in asking for government assistance.

Quite obviously new nuclear power stations are only competitive where huge subsidies are granted or in countries where nuclear technology is part of the state doctrine and costs are therefore secondary. Wherever in the future the construction of a new reactor is envisaged within the framework of a functioning market economy, it must be expected that investors will call on government support along the lines of the previously mentioned American model of subsidies – to safeguard against rising construction costs, unexpectedly long shut down periods during operation, fluctuating fuel costs and the costs incurred in decommissioning, dismantling and waste disposal which are difficult to calculate. Finally countries will have to deal – largely on their own – with the consequences of any serious accident involving the massive release of radioactivity. No company in the world can do that alone. Insurance companies are only liable for a fraction of the damage and this differs from country to country. But in view of the anticipated total cost their contribution would in any case be rather laughable.

We have seen that nuclear technology occupies a unique place also from the economic point of view. More than half a century after its commercial introduction kick-started by billions' worth of subsidies its protagonists insist on, need and receive further government subsidies amounting to billions for its proposed re-birth – just as if it was a question of start-up capital for its commercial launch. Astonishingly, it is above all the politicians who otherwise cannot shout loudly enough for 'more market' that are calling for and endorsing this exceptional approach as well. These are the

same ones who for many years and in many industrial countries crusaded against providing financial support for the commercial launch of renewable energies – solar, wind, water, bio-mass or geo-thermal – with arguments based on pure market theory. However, there was and is a crucial difference: nuclear energy is past its future, renewable energies have their future ahead of them.

Facing the decision: the future of energy supply

In the light of the climate, resource and financial crises, the discussion on nuclear energy is experiencing a revival in some of the major countries. Behind all the fiery talk of a 'renaissance of nuclear energy' by reactor constructors and their political and media spokesmen also lies a decision that will have fundamental far-reaching consequences. The vast majority of nuclear power stations built all over the world during the first and up to now last great nuclear energy boom are nearing their technical age limit. In the next ten years – and increasingly more so in the following decade – the capacity of nuclear power plants, which is rapidly decreasing according to schedule, has to be replaced. The choices under consideration: the rapid expansion of renewable energies (wind, solar, water, bio-mass and bio-thermal) and an altogether more efficient energy system with an ever decreasing proportion of fossil fuel energies – or alternatively extending the production of electricity generated by nuclear energy into the future. At the present time some of the major nuclear energy countries are predominantly preoccupied with the question of whether they want to keep their ageing reactors on line beyond the originally intended operating time limit. This option is attractive for electricity companies as it enables them to cancel investment decisions amounting to billions and to profit from the cheap costs of electricity production from ageing power stations that had been written off. The additional risk that this inevitably involves is calculable for each individual manager – and he does not reckon with a serious accident especially not in one of his own company's nuclear power plants and especially not during his own generally limited period of responsibility. This is what distinguishes their interests from those of the general public – extending the life spans of reactors increases the risk of catastrophe disproportionately. If all or many nuclear power stations are operated for a longer period of time, the risk of a catastrophic accident increases enormously.

The forthcoming decisions on the question of how the global energy supply can be sustainably designed in a world marked by climate change, population growth, great poverty and finite resources go far beyond the question of how we deal with nuclear energy in future. All the developed industrialised countries and many of the emerging countries (whereas the latter either do not use nuclear power at all or at least not to any appreciable extent) bear the responsibility. One thing is already clear: the new energy system will no longer be exclusively based on large fossil fuel or nuclear power plants. It is moreover certain that the future does not lie in a revival of a high risk technology born out of the interests of the traditional energy industry; dating back to the middle of the last century.

So far there is no renaissance of nuclear energy. What we do have is a renaissance of the proclamations about nuclear energy. And this has not just happened overnight. "Phase-out plans are being revised, new building plans put forward and only in Germany is there one last defiant struggle on the part of nuclear opponents", rejoiced the German weekly *Wirtschaftswoche* in its September 21, 1990 edition entitled "Nuclear Renaissance". Owing to the policy envisaged by the German nuclear industry and its Christian-Democrats and Liberals[5] 'dream coalition' of withdrawing from the nuclear phase-out, there is also, especially in Germany, a renaissance of the conflict surrounding nuclear energy – for some people, a renaissance of hope. In some countries that are significant for the future of nuclear energy there is a revival of a socio-political debate. Its outcome is uncertain.

[5] Conservative CDU and pro-business FDP

The new building projects known to have been authorised so far are not even enough to maintain the contribution of nuclear energy to the global production of electricity – not in absolute terms and certainly not in relative terms.

Up to now, nuclear power station projects only exist where this form of electricity production shapes part of the state doctrine or where governments are prepared to advance billions as a safeguard against the security and financial risks involved. Anyone wanting to build new nuclear power stations or is politically encouraged to do so – as for example in the USA or in the UK – needs the government almost as much as the pioneers of nuclear energy did in the 1960s.

It sounds paradoxical but the commercial launch of nuclear energy at the time was made possible because no electricity market existed that could have made it an inefficient proposition. Because on the one hand the provision of electricity was considered overall to be a 'natural monopoly' owing to the electricity grid monopoly, and on the other hand, being one of the general public services it was provided by state-owned or similar companies – in any case by quasi-monopolies. Therefore, in most industrialised countries it was the government that initially led the way in launching nuclear energy for overt or secret military and later industrial-political reasons. The government bore the immense costs of research, development and the commercial launch of the new technology either directly or it ensured the shifting of these burdens onto the consumer through its influence on the electricity price structuring of the electricity suppliers.

In a functioning deregulated electricity market the building of new nuclear power stations is as yet not an attractive proposition for companies. It is not only in the USA that there are much more financially attractive options with nowhere near comparable economic risks. Therefore no new nuclear power stations are built within a free market economy even if electricity demand and power station output increase overall – unless the public purse bears once again a large proportion of the financial risks as it once did at the launch of nuclear energy. That is what they did in Finland and that is what they will do in America unless the policy change that many experts are anticipating under the Obama administration really does result in the cancellation of the long-awaited planning approvals for new reactors. Neither can the route of generous subsidies be generalised as in a functioning power station construction market the competitors from other sectors – namely and increasingly more importantly from the renewable energies sector – will not sit by idly forever and watch the government one-sidedly subsidise a 50-year old technology. This criticism is already being heard in the USA. For instance in 2009 representatives of the Natural Resources Defence Council before the US Senate demanded that the construction of a series of reactors already tried and tested abroad should not be given financial support again in the USA, saying that the nuclear route signified not only market interference to the detriment of other technologies but also led to an economically inefficient route being taken in the change to a low-carbon energy industry (Cochran/Paine 2009).

At the beginning of the 21st century an impartial reappraisal of all aspects of nuclear energy leads to an unequivocal conclusion – it is the same as it was 30 years ago:

- *The risks of catastrophe* which at the time made nuclear energy the most controversial form of electricity production have not been overcome

- *The new dangers of terrorist attacks* categorically rule out an expansion of this technology in insecure regions of the world

- The global expansion of electricity generated by nuclear power would lead to a *shortage of uranium fuel* even more quickly than if the status quo were maintained – or else force the blanket changeover to breeder technology. Such a new technological orientation would be tantamount to

committing nuclear technology to the so-called plutonium path once and for all. It would raise the risk of catastrophic accidents, terrorist attacks and the proliferation of nuclear weapons to a new, even more critical, level.

- With or without breeder technology *the problem of permanent disposal* is not solved either. A solution will have to be found as the waste is already with us. But it will only ever appear to be a solution. In itself that would be a sufficient reason not to further intensify this problem afflicting mankind by increasing the volume of waste.

- Nuclear energy *cannot solve the climate problem*. Even concentrating all means available on this technology, which would be devastating for progress on the whole, would only lead into a belated and modest contribution to climate protection – if at all. Lacking any industrial capacity for extension, owing to the immense costs and a multiplication of the attendant risks involved, nuclear energy would be just as unrealistic as it would be irresponsible. On the contrary, it is predictable and more likely that in the light of the age structure of existing power stations there will be a considerable decrease in global reactor capacity in the coming decades. At the same time there are solid predictions that a global energy strategy which above all focuses rigorously on the development of renewable energies and also on more efficiency in the energy, industry and transport sectors and in heating systems will be able to achieve the necessary reductions in CO2 emissions – even without resorting to nuclear energy. The challenges that this involves are huge but so are the possibilities. Overcoming these challenges requires nothing less than a world energy policy in which sooner or later all the nations responsible for global greenhouse gas emissions pull together. The alleged conflict of aims – 'climate protection or nuclear energy' is a chimera born out of the interests of the nuclear energy industry.

After all this it is clear that there will be no revival of nuclear technology in the foreseeable future without massive government financial intervention. This does not of course mean that it is out of the question. If a catastrophic accident does not stop the expansion in China – and may the people living there be spared such a fate – dozens of reactors will go on line there. And this will continue until the money runs out or the large power stations even in China halt the expansion of the then less expensive renewable energies. All over the world it is not so much the electricity industry, which above all wants to continue to make use of old investments that have been written off, but rather it is politics that is bringing nuclear energy into the equation – in the light of diminishing fossil resources, greatly increasing energy prices and in the anticipation of rigorous obligations towards climate protection. All three aspects are driving the debate in the USA, even after the changeover from the fervent nuclear power supporter George W. Bush to the moderate sceptic, Barack Obama. And it is these aspects that triggered the construction of the new reactor in Finland, the campaign to withdraw from the nuclear phase-out in Germany and the discussion surrounding the construction of new reactors in many other countries.

All over the world politicians tend to plan and continue within the established structures and with the economic players that they are familiar with. Some of them therefore will not hesitate to grant once again financial support for the 'market launch' of nuclear energy more than half a century after the start of the commercial production of electricity in nuclear power plants – as if it were the most natural thing in the world. In Germany the construction of a new reactor is not on the agenda for the simple reason that no potential reactor builder is willing to undertake an incalculable economic risk of this kind and because no majority support among the general public for radiation technology is anywhere in sight. Instead of this, RWE, E.on, EnBW and Vattenfall intend to live off the reserves for a few more decades – at the expense of the safety of all. And politicians of the Christian-Democrats and Liberals coalition government are at their service. They are prepared to prolong the life spans of ageing reactors and in precisely this way they are helping the companies to make

surplus profits amounting to billions – companies whose market dominance they deplore at length in their soap box oratories.

But in any case, the principles of logic hardly ever play any real part in the fundamental conflict surrounding the future of nuclear energy. As early as October 2007 the arguably most renowned scientific journal, *nature* commented thus on the development: "The nuclear energy industry needs climate change more than climate change needs the nuclear energy industry. If we want to avert catastrophic global warming, why should we choose the slowest, most expensive, most ineffective, least flexible and riskiest option? In 1957 it was right to attempt this with nuclear energy. Today nuclear energy is simply an obstacle in the transition to a sustainable electricity supply."

There is really nothing more to add.