Part I

Sun or Atom: The Fundamental Conflict of the 21st Century

There is one forecast of which you can already be sure: someday renewable energy will be the only way for people to satisfy their energy needs. Because of the physical, ecological and (therefore) social limits to nuclear and fossil energy use, ultimately nobody will be able to circumvent renewable energy as the solution, even if it turns out to be everybody's last remaining choice. The question keeping everyone in suspense, however, is whether we shall succeed in making this radical change of energy platforms happen early enough to spare the world irreversible ecological mutilation and political and economic catastrophe.

How far we remain from recognizing the signs of the times is something that developments in the 1970s showed us. Before the outbreak of the global oil crisis in 1973, world energy consumption, according to statistics from the International Energy Agency, came to 6034 million metric toe. In 2002 the figure was 10,213 million metric tons – an increase of 69 per cent, more than two-thirds. Throughout this period renewable energy's share remained constant at barely 14 per cent. Actually its share is substantially smaller than that. The renewable share consisted of 85 per cent biomass in 1971 and then 80 per cent in 2002 – and in developing countries this was largely based on ruinous exploitation of local vegetation, without replanting, which is why the label 'renewable' is so misleading here. The share of nuclear energy during these three decades, by contrast, rose from 0.5 to 6.8 per cent of world energy consumption as captured by statistics. It would have been substantially higher had it not been for the setback brought about by public protest movements against nuclear energy, public referenda, the reactor catastrophe at Chernobyl, the collapse of the Communist bloc, and the (partial) liberalization of electricity supply in the interim.

The objection that technology was not advanced enough during these decades for renewable energy to be feasible is a flimsy excuse. This is even corroborated by the size of the Organisation for Economic Co-operation and Development (OECD) countries' research and development (R&D) expenditures for renewable energy research, which have stood at around 8 per cent of energy research funds for three decades. For nuclear research, by contrast, the OECD country average was 51 per cent. These proportions would turn out looking even more favourable to nuclear energy and slanted against renewable energy if the statistics compiled by the IEA had also included R&D spending by the EU Commission, especially the EURATOM (European Atomic Energy Community) agency's funds, as well as France's unpublished expenditures. There are only sporadic published figures about practical market-launching programmes going beyond R&D. At the end of the 1980s, Brazil started its bio-alcohol programme for fuels. Vehicles were introduced that could cover over 90 per cent of their petrol requirements using bio-alcohol. Between 1983 and 1987 alone, more bio-alcohol than petrol was used in Brazilian cars; bio-alcohol production rose from about 2 million (metric) tons in 1980 to 12 million (metric) tons in 1986. But then this trend stagnated for a long time because the worldwide drop in oil prices again dampened any motivation to save petrol, while there was simultaneously a sharp rise in the number of cars – so that, as early as the 1990s, gasoline consumption was again much higher than bio-alcohol consumption. The Brazilian programme was not even imitated by other countries that enjoyed similar opportunities for cultivating sugar cane.

Since the beginning of the 1990s, 350 megawatts of capacity have been available in California for solar-thermal power –

but then there was a worldwide stop to any new solar-thermal investment until 2004. Small hydroelectric power plants using running water have been around for over 100 years, yet there has hardly been an effort made to multiply their numbers. In Denmark, the share of wind-powered electricity in total electricity supply grew from 0.1 to 16.4 per cent between 1980 and 1999, all this without the cost of Danish electricity climbing disproportionately. Yet in spite of this practical demonstration that there is a different way of doing things, the share of renewable energy in overall demand among the other industrial countries' power supply sank noticeably during this time period: in Australia from 18.5 to 8.3 per cent, in Canada from 75.5 to 57.9 per cent, in Finland from 42.1 to 29.1 per cent, in France from 39.4 to 14.4 per cent, in Italy from 38.3 to 20.1 per cent, in Portugal from 80.5 to 34.6 per cent, in Spain from 49.4 to 21.9 per cent, in Switzerland from 88.9 to 59.8 per cent, in Turkey from 37.1 to 19.8 per cent, in the US from 15.5 to 7.4 per cent, in Ireland from 13.8 to 4.2 per cent and in Greece from 26.8 to 5.5 per cent. Apart from Denmark, Germany was the only country in which there was an increase in the share of renewable energy starting in the 1990s. All this goes to show that the growing demand for energy everywhere was met almost exclusively by fossil or nuclear energy, so that the share of renewable energy – most of which continues to be managed using old power stations at dams – kept getting smaller and smaller. Thus, Greece preferred routing electricity from coal-fired plants on the mainland to its wind-swept islands via underwater cables instead of erecting on-site wind power facilities.

Renewable energy – as Wolfgang Palz, long-time division chief for renewable energy at the EU Commission, had already explained in 1978 in a UNESCO publication *Solar Electricity* – was often better poised for introduction into the market than nuclear energy had been in its day.[1] But, even in the 1990s, every other conceivable measure seemed more important to political institutions than slowing down the trend of utilizing conventional energy sources: measures such as liberalizing electric power markets for the sake of lowering the price – and therefore increasing the consumption – of environmentally damaging energy sources. Or measures like easing international powers' access to fossil raw materials by making them duty-free. An additional factor has been the rapidly forced industrialization of Asia, with China and India in the lead, two countries that together make up more than a third of the world's population. Craving a share in the world economy's biggest potential growth market has shunted aside our understanding that this development is incompatible with sticking to traditional energy supplies. There are no tenable justifications for the various denials of renewable energy in mind and deed. All these excuses have one thing in common: they are untenable in view of all the crises brewing worldwide, crises whose origin lie partly or wholly in nuclear or fossil energy. This is especially true of the standard argument that renewable energy would not 'pay off' in the market-place – as if fossil and nuclear energy would have been able to prevail entirely and solely without political assistance in the past, and as if they would be capable of holding their own today without political support.

The long-ignored signals

The keynote of the signal to liberate us from our dependence on fossil energy was sounded by universal-minded scientists even before the Fossil Age had fully unfolded. At the dawn of the 20th century, Wilhelm Ostwald, who received the Nobel Prize for chemistry in 1909, spoke of the 'unexpected legacy of fossil fuels' that (mis)leads us into 'losing sight temporarily of the principles of a durable economy and into living from one day to the next'. His clear-sighted conclusion was that a 'durable economy' needed to be based 'exclusively on the regular influx of energy from the sun's radiation'.[2] In those days Ostwald was probably thinking in terms of a longer time period before this 'energy imperative' would have to be realized. Nobody in his day could have foreseen the growth in world population, which quadrupled over the last century. Nor was it possible to foresee the century's explosive economic growth, including the rise in consumption that (especially in the second half of the 20th century) triggered a worldwide orgy in fossil energy consumption. The industrialized world plunged into an energy delirium – a sustained state of intoxication that animated the rest of the world to imitate it and obscured everyone's senses in a kind of smokescreen. In the 20th century Ostwald's oracle was increasingly suppressed as more evidence piled up corroborating it. The Swedish scientist Svante Arrhenius, who won the Nobel Prize for chemistry in 1903 and later became director of the Nobel Institute, also wrote this in his 1922 book *Chemistry in Modern Life*:

> *Concern about raw materials is already casting a dark shadow over mankind. Concerns likes those about petroleum are also warranted owing to the future of almost all raw materials. Every industrialist seeks to push his production as high as possible in order to achieve the largest conceivable profit, and he gives no thought whatsoever to how things will be after fifty years or half a century. The statesman, however, needs to apply a different standard.*

Arrhenius was already warning about brutal international conflicts over energy:

> *States lacking [in raw materials] cast covetous glances at their neighbours, of whom it is said that they have more than they need. And the result is that profit-seeking will be increasingly lured into those countries whose interests are not guarded by judicious men. Future historians will bring to light how much craving raw materials for the future is to blame for [our] great misfortune.*

Fossil raw materials should therefore not be abandoned to 'national egoism' and 'industrial profit-seeking'. Mankind needs to arrive at the insight that it must 'replace [those raw materials] with the manpower that the sun pours out over us in inexhaustible amounts', whether directly or 'indirectly via the amounts of energy originating from the sun, amassed in streams of water and greening plant life'.[3]

Natural scientists – for whom it was more than self-evident at the beginning of the 19th century than it is today to think about the universal picture – were not the only ones who had an early awareness of these problems. In 1908 President

Theodore Roosevelt convened a governors' conference in order to initiate compiling an inventory of raw materials not yet exhausted and to catalogue the health defects and destruction of natural resources caused by raw materials exploitation. In 1909 the National Conservation Commission he designated for this purpose submitted its report, which called for resolute measures to reduce emissions and save energy, to substitute water power for coal, and to use solar heat, alcohol and other organic fuels. Roosevelt called on 45 world governments to come to an international conference in The Hague in order to discuss the worldwide consequences of resource exploitation.[4] This conference never came about, and even the National Conservation Commission discontinued its work because Congress refused to fund it any longer. Roosevelt was the same man who had an early grasp of the danger to the US's democratic constitution emanating from the petroleum trust run by Standard Oil boss John D. Rockefeller, and he started a campaign against the Rockefeller monopoly. That campaign ended in 1911 when the Supreme Court decided to enforce the Sherman Act against Standard Oil and dissolve the conglomerate into several independent corporations (such as Esso, today's Exxon).[5] This first large-scale political initiative against the fossil industrial energy complex remained a mere episode, however. There followed a century rife with environmental destruction caused by the use of fossil energy and of an increasingly internationalized concentration of power in the energy business. New discoveries and new drilling and mining techniques repeatedly provided new excuses for brashly repressing awareness of the mounting dangers.

Falling back on the sun was felt to be a relapse back to a time before the Industrial Revolution and, by extension, to the conditions of 10,000 years of civilized history in which human beings satisfied their energy needs almost exclusively with renewable energy. The opportunity to use renewable energy optimally by taking advantage of modern technology was not taken into account – this in spite of technologies that had already been developed for this purpose in the 19th century.[6] Yet the limitations of fossil energy were known to the world of the physicists. Once atomic fission was discovered, the prevailing view was that there was an historic path from using solar energy in pre-industrial times, to utilizing fossil energy created over millions of years inside the Earth, to nuclear energy. The possibility of acquiring colossal amounts of energy from nuclear fission or fusion fascinated scientists as much as it did governments and the public. It seduced them into a sense of omnipotence that regarded all risks as manageable – at least the risks associated with the 'peaceful use of nuclear energy' or even of nuclear weapons, which were assigned the role of deterring wars.

In this way the basic pattern was woven for worldwide energy conflict in the second half of the 20th century, the pattern that is also shaping the first half of the 21st century. Nuclear energy became the reinsurance policy needed to resume the world's intoxication with energy consumption even when claiming, all the while, that the environmental sins of fossil fuels could be ended some day. Atomic energy also rationalized ignoring renewable energy as something supposedly backward-looking. An arrogant fossil/nuclear world view emerged. Its sponsors could not concede that they had misjudged and were being haughty. They steadfastly invoked the indispensability of nuclear energy.[7] The cost for its expansion could go as high as one liked so long as its world view would never have to capitulate before renewable energy. The expense incurred for its introduction dare not have been in vain. The conflict between 'solar' and 'atom' – between embracing renewable energy or continuing down the path taken in the 1950s, initially by way of nuclear fission, later via nuclear fusion – is, above all else, a structural conflict linked to world views. It is played out using superficial technological and economic rationales that conceal the very things for which the advocates of renewable energy are reproached: ideological fixation and technological pipe dreams. This basic conflict was not apparent for some time, or to put it more precisely, it did not become visible until nuclear energy became discredited by the fateful warning of Chernobyl in 1986.

The smouldering fires of seven energy-determined world crises

Yet the supporters of the fossil/nuclear world view have been making their calculations without taking into account the world-wide crises that, in spite of all the attempts at cover-up, keep getting generated (directly or indirectly) by nuclear and fossil energy. Seven grave crises may be discerned. Every one of these is well-known, yet each is usually only viewed in isolation rather than in the required synoptic perspective.

The global climate crisis

In 1988, the final declaration of the World Conference on the Changing Atmosphere (the upshot of an initiative of the Intergovernmental Panel on Climate Change established by the World Meteorological Association and the United Nations Environment Programme) stated that the world, because of its fossil energy consumption, was letting itself get involved in an experiment whose consequences would come to resemble those of a nuclear war. The number of individual catastrophes – storms, floods, droughts – is on the rise, and they are going to become more severe. They are even taking place earlier than most meteorologists have predicted. The major impending threats are probably those relating to the rise of the sea level, warming water, and changes in ocean currents. Attempts at placating concerns about these dangers by pointing to similar occurrences in the history of the Earth do nothing to remedy the climate crisis. These precedents took place in periods when only a few or no humans at all populated the Earth. What humans create today also needs to be avoided by doing everything humanly possible. We are threatened by the prospect both of major areas of settlement becoming uninhabitable and of gigantic expanses of land becoming degraded – and all this means mass movements of people in flight. These kinds of damages ensuing from today's climate catastrophes do not show up in any energy bill.

The exhaustion and dependence crisis

The most explosive problem about fossil energy supplies is the growing dependence of more and more countries on fewer and fewer production sources, especially for petroleum and natural gas.[8] Today the US is dependent on imports for up to 56 per cent of its energy requirements, Germany for 80 per cent and Japan for up to 95 per cent of their respective energy demand. The days of 'easy oil', of petroleum deposits that can be extracted relatively effortlessly and cost-effectively, will be coming to an end in just a few decades. The same goes for natural gas – although this is readily overlooked – which largely comes from the same oil-producing countries.[9] This means that about 60 per cent of today's global energy consumption will be up for grabs over the next several decades. Declining reserves on the one hand and growing demand on the other inevitably lead to rising energy costs, which harbour drastic dangers for the world economy and threaten to tear apart the social fabric. Increasing conflicts over these reserves' availability, including wars over 'cheap' residual resources, are pre-programmed into this development. The major portion of petroleum reserves still available resides in the arc of Islamic states that – not least of all owing to oil – has become an overheated crisis region, while another major portion of additional reserves may be found in the Islamic-Caucasian area, also a crisis region. This imparts an even greater explosiveness to the dependence crisis.

The poverty crisis in the developing countries

Developing countries without fossil resources of their own, and this is the world's majority, have to pay the same amount for energy imports on world markets as all the other countries, and each one has do this with a per capita gross national product (GNP) that is well under 10 per cent of the Western industrial countries' GNP. De facto, therefore, developing countries as measured by their economic efficiency face a burden that is greater by a factor of 10 or more because of their energy imports. At the same time, owing to a lack of networked infrastructure for energy supplies, these countries are economically even more dependent on non-pipeline-connected petroleum than the industrial countries. The consequences of energy poverty are ruinous exploitation of biomass, increasing steppe land, rural flight into the cities' overflowing slums, the destruction of social structures and the disintegration of states, and crises that spill over into international conflicts.[10] And yet, in a grotesque misjudgement of reality, using indigenous renewable energy to overcome this energy-determined poverty crisis is deemed economically unreasonable.

The nuclear crisis

Since the 1990s, more and more countries have wanted to equip themselves with nuclear weapons. The essential reason for this is that the nuclear powers (the 'haves') continued to insist on their own nuclear armament even after the Cold War was over. Above all, the US has insisted on this stance (and, as part of the US retinue, NATO strategy has also clung to this position), in spite of the overwhelming quantitative and qualitative superiority of its conventional weapons and troops. The result is that the international two-class system of 'haves' and 'have-nots' established in 1970 by the Non-Proliferation Treaty is less and less accepted by up-and-coming regional powers, and especially among the countries of the Islamic region. They see an additional legitimation in the belief that they would never be treated the way Iraq was if they had nuclear weapons. The US's gentle behaviour towards North Korea, which has a nuclear weapons potential, confirms this.

Access to a nuclear weapons potential and hiring experts to build one have become easier than ever: whether covertly, by finding scientists from the ruins of the former Soviet Union and hiring thousands of unemployed nuclear weapons specialists, or officially, by using the right inscribed in Article IV of the Non-Proliferation Treaty guaranteeing all (currently 138) signatory states technical assistance when it comes to 'applications of nuclear energy for peaceful purposes'. Whoever possesses the essential components of the nuclear fuel cycle, meaning reactors and the opportunity to enrich uranium and reprocess nuclear fuel (even if only on a small scale), is just a few quick steps away from possessing nuclear weapons. The deadline for giving notice on abrogating the Non-Proliferation Treaty is just three months. Not only can the technological boundary between civilian and military applications be quickly crossed, it is just as easy to transgress the political demarcation between 'peaceful' and military uses. There is also the growing danger posed by nuclear terrorism. On 11 September 2001, the world found out that fundamentalists do not shy away from mass murder at the cost of sacrificing their own lives. They could use nuclear terrorism to become a world power – not through the relatively complicated deployment of atomic weapons, but by means of less complicated kamikaze attacks on nuclear power plants or via acts of sabotage producing large-scale nuclear radiation.[11] The civilian use of nuclear power is a 'child' of its military application, and this is not a paternity easily shaken off.

The water crisis

The total amount of water on the planet has, to be sure, remained constant. Even evaporated water directed into the atmosphere returns to the Earth's surface – although not necessarily to where it is needed. Condensed fresh water that falls as rain into the oceans becomes salt water there. The freshwater crisis in many regions of the globe (increasingly a problem in the northern hemisphere as well) is attributable in large measure to nuclear and fossil energy. Three-quarters of Germany's water consumption as registered in statistics, and about 50 per cent in the US, originates from the demand of nuclear and fossil steam power stations![12] This water escapes into the atmosphere or is returned in heated form to rivers, which thereby impairs water ecology. The problem is even more serious in water-poor regions. The competition between people's immediate need for water and their indirect water needs because of agricultural production is a conflict that has frequently been described. By contrast, the competition that exists between these needs and the water requirements of the nuclear and fossil energy system has largely been overlooked thus far.[13]

In addition to what is required for steam power plants, there is a significant demand for water to wash coal that has been mined or for oil production (in order to create the pressure needed to extract petroleum). And then there are those serious disturbances of ocean and water ecology with their negative consequences for fish life and other habitats, or the damage caused by tanker accidents and diesel leaks from motorized ships and boats. One drop of fossil oil contaminates a cubic metre of water. Nitrates from petroleum-based farm fertilizers also damage the water table. The water crisis is to a large measure the result of the nuclear and fossil energy system.

The farming crisis

The same goes for the crisis of modern farming. Because of agriculture's shift away from using home-grown energy, including fertilizer, to chemicals, all the sectors bordering on agricultural production have become steadily more dependent on the energy business. The purchasing costs of fertilizer and energy have grown enormously and diminished farmers' incomes. The response to this cost-income squeeze has been heightened production using more fossil-based energy and fertilizers – an ecological and economic vicious cycle. In addition, the compulsion to increase production is a driving force behind the transformation from a more peasant-rustic type of farming to an industrial kind of agriculture – a development leading to the destruction of rural livelihoods that increases the general level of unemployment and destroys the culture of rural areas. Moreover, soils become overtired – to the point of degradation. Developing countries that are dependent on oil imports, furthermore, cannot keep up with this fossil-based increase in agricultural production – and when they try to keep pace, they can only do so at an economic cost that is disproportionately high.

The health crisis

That health defects result from the normal operation of nuclear power because of radioactive contamination is a fact that has been repeatedly denied. But it is indisputable that this happens in uranium mining. When it comes to health defects from fossil energy, the results are even clearer, something that has been confirmed by the World Health Organization (WHO) and articles published in *Science*, one of the most reputable science magazines. Roughly one-quarter of humankind is therefore adversely affected by energy emissions. According to one study, which covered only Austria, France and Switzerland, these discharges lead annually to 800,000 cases of asthma and bronchitis and 40,000 premature deaths. And yet these countries have comparatively strict emission regulations. In China, premature deaths from 'outdoor emissions' are estimated at 290,000 annually, and in India at around 200,000. In China, according to World Bank research, fossil-based air pollution costs US$50 billion in health damage annually, which corresponds to 7 per cent of GNP. In the EU, these costs are estimated at US$70 billion.[14]

One WHO estimate puts the number of premature deaths at 1.8 million annually in Africa alone, where women and children are especially affected, in particular by 'indoor emissions', meaning traditional wood burning in houses and huts lacking technological opportunities for better energy use like energy-saving wood-burning stoves, solar collectors or solar electricity.

Reciprocal crisis infection

It is no accident that the crises sketched out here have shown up at the same time. The higher the level of energy consumption, the more this heats up all the accompanying problems (as in a system of interconnected pipes and ducts). A small harbinger of what can happen here was Italy's electricity supply crisis in the summer of 2003. A heatwave probably attributable to climate change had gripped half of Europe, especially Italy and France. Alpine reservoirs received less water, while rivers and streams dried out. The region's steeply rising power needs for electrical cooling systems collided with the hydroelectric power plants' sinking production. Even French nuclear reactors delivering electricity to Italy had to stop production for lack of cooling water from rivers. For weeks there were long stretches of time every day in which abrupt power failures were experienced. Industrial activity had to be stopped, computer systems crashed. Harvest failures, with their concomitant agricultural losses, reached all the way to northern Germany. The climate crisis had triggered a water crisis which, in turn, led to an acute power supply and agricultural production crisis.

This concatenation shows what awaits us over the next several decades if the world is unable to liberate itself post-haste from nuclear and fossil energy dependence. One need not even conjure up one of those oft-repeated horror scenarios about northern Europe losing its warming Gulf Stream and therefore entering an ice age, or about all the world's coastal regions becoming inundated and permanently uninhabitable, nor even about the dangers of a nuclear reactor meltdown. These dangers are more or less probable, but they are always assessed as hypothetical. No longer hypothetical is the kind of crisis escalation just depicted, a scenario quite likely to become more frequent.

Because of the climate crisis, the number of victims directly affected by catastrophes is bound to swell. The crisis will also increasingly impair both the ability of states to act and living conditions for the general public. Insurance companies will get into financial straits, from which they will be able to extricate themselves only by increasing premiums and removing climate risks from the protection their policies offer. Social compensation measures for people who have run into trouble, along with repair services for public infrastructure, are going to strain government budgets or compel higher tax burdens. The costs of compensating damages from environmental crises caused by outdated forms of energy reduce the financial leeway needed to provide for a future based on renewable energy. States that can summon up neither the financial nor the organizational energy to redress these catastrophic damages will be forced to abandon people to their fate. There will be more victims fleeing devastated regions for lands not yet endangered – and the number of uprooted and impoverished people will also be on the rise.

A political state of emergency is therefore pre-programmed into every oil and natural gas exhaustion crisis. There might also be surprises in store if a government were to be overthrown – for example, if Saudi Arabia's feudal regime with its hydraheaded monarchy were to be ended and replaced by a fundamentalist Islamic regime that might throttle and stretch out the timetable for oil production in its own long-term interest. Or there could be a political-military conflict encompassing the entire Persian Gulf region if the US should decide to use force to prevent Iran from acquiring nuclear weapons and thereby trigger a multi-country conflagration involving uncontrollable mass unrest. An additional scenario might be a rapid increase in relatively risk-free terrorist attacks on oil and gas pipelines, which run along stretches extending for tens of thousands of kilometres that are not reliably guarded. Attacks of these kinds could interrupt world oil supplies and plunge the global economy into a maelstrom. As early as 1980, one Pentagon study had already warned about this eventuality and therefore issued an urgent recommendation for conversion to renewable energy.[15] The political-military cost of securing oil supplies will rise in any case, as will political pressure from the US on other industrial countries to share in defraying this cost. It is no accident that China is rearming so that it can secure its international resource interests from a position of military strength.

But even if none of this happens (which we can only hope, though it is hardly a realistic expectation), the rise in the price of oil, because of its inevitable shortage, simply cannot be stopped by the evasive manoeuvre of falling back on nonconventional reserves. There will be increased domestic political pressure on governments to lower energy taxes so as to relieve citizens from the burden of drastically rising energy prices. A foretaste of this was supplied by the Europe-wide protest against fuel taxes in the autumn of 2000 after a rise in oil prices. A current event signalling the same problem is the legislation introduced by the Bush administration in April 2005, whose aim is to arrange tax breaks in the order of US$8 billion for companies producing coal, natural gas and petroleum as well as nuclear energy within the US.

If governments cave in to this pressure, they are endangering their public budgets. If they do not, economic and social distress will still be on the rise. 'Developing countries' will ultimately suffer economic collapse under the weight of price increases for oil imports, and this will accelerate their political institutions' decline to such an extent that industrial countries and international organizations will be hopelessly strained trying to provide assistance. Even those countries that have placed their bets on tourism as the sector carrying the burden of economic growth will suffer severe losses, since more expensive oil is going to stem the flow of international air traffic. The attempt made by the Gulf state Abu Dhabi to face up to the imminent drying out of its oil wells and adjust to the post-Oil Age ahead of time by building seven-star luxury hotels is probably condemned to failure if there are no longer enough tourists to sustain it.

And anyhow, what will happen with and inside the oil-producing states if their oil wells run dry quickly? Most of these countries have hardly taken precautions about the post-oil era, and they have carelessly neglected to promote small- and medium-sized industry as well as agriculture, as the political scientist Hartmut Elsenhans has noted.[16] And what are the prospects for Russia and the Central Asian oil- and gas-producing countries when their chief income source runs dry? Will they all follow the advice clamorously offered again to place all their bets on nuclear energy – and to do so in the midst of domestic turmoil, with fragile institutions lacking democratic foundations, and against the background of a newly rekindled Islamic–Western culture war? Will this not lead inevitably to the proliferation of nuclear powers? The world will be threatened by ruinous turbulence if, owing to unfounded fear of the shift to renewable energy, countries continue to play with nuclear and fossil fire. One is reminded of the pattern of behaviour in an ancient Greek tragedy, in which everything rushes towards a disastrous end. Everyone involved can see this coming, but nobody can release himself from his own behavioural compulsion contributing to the tragic denouement.

The many ingenious scenarios painted by conventional energy experts are built on an assumption that became unrealistic a long time ago – namely the possibility of somehow maintaining global stability in spite of energy crises flickering up all over the world and then shifting the costs for this onto the general public. Those who provide this kind of advice like to certify their own superior sense of 'realism', which they derive from the dominance of the traditional energy system and from the conventional prevailing wisdom (heavily influenced by that system) among political, economic and scientific 'elites'. Yet 'realism', above all else, is something that flows from a clear perspective on problems. Concepts and plans that do not provide any answer to these problems are not realistic; they are unreal. The basic requirement of realism is not being fooled by anything. The reality is that the world is now confronting the greatest challenge in the history of civilization and, in spite of this, has not faced up to this challenge in the appropriate manner. By consorting with fossil and nuclear energy, the world has got itself entangled in two 'Promethean' grand experiments from which it has no inclination to extricate itself of its own accord. Prometheus, of course, is that figure from Greek mythology who stole fire so he could take over the power of creation. For this he was terribly punished, and the fire was ripped from his hands by the gods. Since we do not live in a world of mythological sagas, we need to rely on social forces to put the nuclear and fossil fireplace on ice. An orientation towards renewable energy does not require some grand new technological Prometheus, like nuclear fusion, to whom the energy technicians of the industrial modern age keep calling out.

What society is going to be capable of taking decisive action in order to create a new, survival-guaranteeing energy foundation when the wildfire of energy crises has completely spread out all around us? How many people in this interconnected world will then be swept along into the abyss? Will it take a variety of catastrophes whose consequences are still containable before a definitive breakthrough towards the necessary shift in energy resources is triggered? Or will we succeed in forestalling such developments with rational action just in time? Both of these possibilities – a comprehensive shift to renewable energy *or* its 'long-term' postponement – have revolutionary consequences, albeit in extremely different ways. It is the difference between a positive and a negative vision – if the standard by which we measure policy and political action includes the human right of everyone to energy, climate and environmental protection, economic and social stability, and securing life and peace.

Enough energy for all: The sweeping potential of renewable energy

The fact that renewable energy can satisfy the world's entire energy needs has been explained repeatedly in detailed scientific scenarios since the 1970s: on a global scale, for the US, repeatedly for Europe, for Germany and Japan, for Sweden or Austria – and also for regions within individual countries.[17] What all these studies have in common is that they get systematically ignored in discussions about energy, even by relevant environmental institutes.

The different scenarios were drawn up using an 'inductive' method: they proceed from assumptions about current and expected supply and demand potentials for energy and then calculate in the possibilities for saving energy and increasing energy efficiency. At the same time, they shed light on the different forms of renewable energy according to their specific supply opportunities within the different sectors of energy consumption. Yet all energy scenarios, even those for renewable energy, are inevitably a glass bead game; no economist from the vantage point of today – even assuming that developments are relative – can estimate what the costs of traditional energy compared to those for renewable energy technologies will be in 2025 or 2040, and it is especially difficult to estimate expenses for technologies that are still young or have only recently been introduced. Yet even if no energy scenario can ever cover every facet of future developments, in principal it can at least sketch out what is possible and describe goals that are achievable so that appropriate action may be encouraged.

The opportunity for a complete shift in energy

In order to demonstrate the plausibility of energy supply based exclusively on renewable energy, therefore, it should suffice to employ a much simpler method. Based on a natural potential that vastly exceeds all traditional energy sources in quantitative terms, on technologies already available today (including opportunities for applying them), and with a little willingness to join in some creative practical thinking, one could plausibly make the case that it is possible to replace traditional energy with renewable energy.

Electricity as an example

In 2001 annual commercial electricity consumption worldwide came to 15.5 trillion kilowatt hours. In order to make this amount of electricity available exclusively through wind power, one would need to install – based on 2.5-megawatt facilities that produce 6 million kilowatt hours a year at medium-range wind speeds – 2.5 million wind power facilities around the globe. In order to create the same amount of electricity with photovoltaic facilities, one would need to install – assuming a production rate of 75 kilowatt hours of electricity per square metre of solar cell area and per year, which is a relatively small value under German insolation conditions – around 210,000 square kilometres of solar cells worldwide. That is much less than the built-over surface area of the EU alone, an expanse into which solar cells could be integrated in a variety of ways. When it comes to solar-thermal power plants, roughly 15,000 square kilometres of collectors would have to be installed – based on a calculation that about 1 million kilowatt hours are produced per hectare of collector space per year – especially in desert regions or on areas otherwise not used.

Thermal heat as an example

In order to satisfy the world population's current need for heat using solar heat, it would suffice – as measured according to consumption from the year 2001 at 3.34 trillion kilowatt hours – to have 15,000 square kilometres of solar collectors, calculated on the basis of just 2.25 kilowatt hours of solar heat production per square metre of collector space.

Bio-fuel as an example

If today's 21 trillion kilowatt hour demand for fossil fuels were to be met by bio-fuels, the amount of forest or farmland acreage that would have to be made available for continuous energy harvests, calculated at an average energy yield of 50,000 kilowatts per hectare, would come to 4.19 million square kilometres. This corresponds to using about 8 per cent of the world's forest, field and farmland acreage for this purpose – with regrowth cultures for which annual harvests would have to correspond to the biomass potential that would be regrowing again the following year. But in semi-arid regions there is an additional cultivatable potential of well over 10 million square kilometres, and above all there is the usually overlooked potential of water plants in the form of algae cultures or water hyacinths.

These are projections of individual renewable energy options for which (as adumbrated) there is no demand that they be implemented – something that can be seen simply by looking at the case of electricity, where the requirements for meeting world demand are quantified with each one of the three options cited. One therefore needs significantly less from each option than indicated above. Additional options that supplement this picture of a technological potential already within our reach are: 1) water power (already long in use), which currently covers about 18 per cent of the world's electricity consumption and which, in the form of small-scale water power – in other words, without damming up flowing water – can frequently be developed; 2) wave and tidal energy; and also 3) geothermal energy. That this natural energy potential enables an even wider range of technologies to be activated is something that emerges from the basic fact, described elsewhere, that the sun and its derivatives (wind, waves, water and biomass) 'deliver' a daily dose of energy that is 15,000 times greater than what we now consume in the form of nuclear and fossil energy. To speak of insufficient energy potential is therefore downright laughable. It is also nonsense to speak of some limit set by technology, for the issue at hand (given the required volume of production for energy facilities) is the kind of production capacity that has been customary in other industrial sectors for a long time – and in the future even the energy required for these facilities' production can and will be renewable.

What, therefore, is the principal obstacle supposed to be? The projections introduced above serve only to open up our thinking on the subject. The practical attractiveness of renewable energy becomes greater with each step taken towards a closer and more differentiated consideration of its potential for natural and technological application. This attractiveness includes: technological and structural enhancements of efficiency through the avoidance of transmission and transportation costs; the opportunity renewable energy provides for regional and local energy provision; new building forms that drastically lower active heating costs in houses; and major opportunities for mining bio-fuels from the biological waste products of the agricultural and timber industries and from foodstuff production or leftover wood from forestry, expanded by way of new biomass cultivation plans using crop rotation, annual multiple harvests, new gasification and fermentation techniques. The magnitude of all these opportunities expands in regions with above-average insolation, natural water reserves, especially good wind conditions, soil conditions and forest yields. The scale of opportunities also grows with continuous optimizing of application techniques already tested and the development of new ones, and it increases with improvements in techniques for energy facilities' production, for increasing their efficiency, and employing new materials.

Just this spectrum of current opportunities illuminates how supplying the world with renewable energy, even taking into account developing countries' growing energy needs, is something we can already describe. The proportions in which the individual options are mixed will be different from country to country, region to region, from one local community to another, and from house to house. Which mixture is realized in each case cannot be predicted and will depend on many factors: on the effects of energy savings that are achieved, which will lower energy demand parallel to the expansion of renewable energy; on geographical conditions and natural supplies in each instance; on the developmental maturity of each technology, on each technique's degree of industrialization, and on its cost trajectory; on the open-mindedness of economic enterprises and, not least of all, on the state of public consciousness – in other words, on social factors. The only sure thing is that today's widespread uniformity in energy supply structures and energy consumption, which developed on the basis of fossil energy, will become a thing of the past. Every country, indeed every region

Table 1 *'100 per cent scenarios' for energy supply with renewable energy*

Title	*Year of publication*	*Organization*	*Target country/region*
Solar Sweden: An Outline to a Renewable Energy System	1977	Secretariat for Future Studies (Director: Professor Thomas Johansson)	Sweden
ALTER: A Study of a Long-Term Energy Future for France Based on 100% Renewable Energies	1978	'Le Groupe de Bellevue' Scientific group of leading research institutes	France
Energy Strategies: Towards a Solar Future	1980	Union of Concerned Scientists	US
Solar Energy Futures in a Western European Context	1982	International Institute for Applied Systems (IIASA)	Western Europe
Renewable Energy Supply under Conditions of Globalization and Liberalization	2002	Survey Commission of the German Bundestag	Germany
Energy Rich Japan (ERJ)	2003	Institute for Sustainable Solutions and Innovations (ISUSI)	Japan

Target year	Energy carrier mix	Recommended instruments
2015	100% renewable energy: biomass 61.8%; active/passive solar heat 12.5%; water power 11.4%; PV (photovoltaic) 8.8%; wind power 5.3%; oceanic energy 0.2%	No data
2050	100% renewable energy: solar (photovoltaic, solar thermal, CSP (concentrating solar power), passive) 49.5%; biomass 27.2%; water power 13.7%; tide power 5.1%; wind power 4.6%	No data
2050	100% renewable energy; sectoral distribution: building sector 35% (active and passive solar use; short-distance heating, biomass); industry 30% (wind, PV, CHP (combined heat and power, or cogeneration)), CSP; transportation 25% (biomass, H_2, electricity); other 10%	Efficiency standards; tax policy; interest-free credits and subsidies; tax exemption or allowance; renewable energy usage obligation in the building sector; 'Solar Development Bank'; R&D; information policy
2100	100% renewable energy: wind power 33.9%; on-site 28.3%; biomass 15.1%; PV 9.4%; water power 8.5%; solar-H_2 3.4%; wave power 1.4%	No data
2050	94.6% renewable energy: import renewable energy 15.4%	Increase in efficiency: Renewable Energy Sources Act; Renewable Energy Heat Act; expansion of short-distance and long-distance district heating; import of renewable energy; R&D
No data (depends on politics / policy)	100% renewable energy: solar 35.1%; wind power 28.4%; CHP 17.7%; geothermal 13.5%; water power 5.2%	Efficiency standards and labelling; efficiency and renewable energy regulations for building sector; legally binding extension rules for renewable energy; input reimbursements; consumption reduction in transportation

will be getting a specific, and also diverse, energy foundation. Supplying the world with renewable energy will be 'multicultural' (see Table 1).

Of course, all sorts of individual efforts will be necessary in order to realize this vision. But what is required is no more complex or more expensive than the development and production of satellite, aerospace, communications, medicine or weapons technology – and it is less complex by far than nuclear technology. The assertion that it is not possible to arrive at a comprehensive energy supply using renewable energy is an insult to the creativity of physicists, chemists and engineers. And if there are any scientists who assert this, they are only discrediting themselves.

Countless practical examples show that this can work. Since 1994 the most illustrative and outstanding projects have been honoured with the European Solar Prize awarded annually by EUROSOLAR.[18] These include residential homes, for example, but also old buildings, prefabricated houses, school and local government buildings, office buildings, and production sites that meet their entire energy needs – electricity and heat – autonomously using renewable energy. A few of these (like the 'plus energy house') even produce surpluses. The vast majority of these buildings' owners are people earning average incomes. Imagine what can happen if more and more homeowners rethink their energy use along these lines – and, ultimately, if everyone does so because it becomes the social norm. People would be rid of their worries about rising energy prices, city air would be cleaner, the number of the infirm would sink. The city landscape would be changed, especially rooftops, since there would be lots of crystal blue and multicoloured solar panels instead of the kind of red roof tile dominant in German cities. After all, what we are dealing with here – if we add up home demand for electricity, heating and cooling – is nothing less than half of the solution to the problem.

The prizewinners have also included farmers and vintners, who not only meet their energy needs with renewable energy they produce on their own but have also become energy suppliers themselves, as well as firms who tank up their entire fleets of vehicles with vegetable oil; producers of synthetic bio-fuels like 'sunfuel' or bio-ethanol and of the drive assembly technologies related to these fuels; cities and municipal works who supply their residents with electricity and heat from biomass power plants and can completely heat housing developments using solar heat that they store in the ground for the winter. The list includes businesses that have developed passenger boats driven exclusively by electricity from solar cells installed on each boat, entirely noise- and emissions-free, and which transport up to 100 people along the Neckar river in Heidelberg, on Lake Constance, or around the Alster river in downtown Hamburg. Other winners are cities that have bought back their electricity grid and are operating it either themselves or with a municipal civic cooperative. EUROSOLAR also issued awards to islands and small local communities who made themselves energy-autonomous for all their electricity and heating needs. All these award winners instigate others to follow suit.

With a little bit of 'sociological imagination' (to borrow a term from the late C. Wright Mills and the German scholar-activist Oskar Negt), we can appreciate how countless small achievements can be bundled together into a whole new and larger entity. All these examples show that the hurdles are not, at core, technical and economic barriers. What matters are ideas and attitudes that can unleash initiatives. In any event, the basic assumption of an insufficient technological potential is untenable.

The opportunity for rapid implementation

Take Germany's Renewable Energy Sources Act: about 12 per cent of Germany's entire electricity supply was achieved using renewable energy, of which about 8.5 per cent came from 'new' forms of renewable energy, meaning without water power from dams. This 8.5 per cent represents about 25,000 megawatts of power plant capacity initiated because of the Renewable Energy Sources Act. The annual growth in capacity promoted by the Renewable Energy Sources Act and its forerunners comes to about 3000 megawatts, of which wind power has the largest share. Assuming that Germany experiences the same annual growth over the next few decades, capacity would increase to 48,000 megawatts in 2015, 78,000 in 2025, 108,000 in 2035, 148,000 in 2045 and 178,000 in 2054 (note, what we are describing here is an introductory tempo for which there already exists practical proof). At 16,000 megawatts, wind power currently already has the greatest overall potential for renewable energy in Germany. Further developments will make the renewable energy spectrum more pluralistic. The tempo of change that has already been reached does not even have to be sustained for decades on end in order for us to arrive at a situation, 40 to 50 years from now, in which nuclear and fossil energy will have been completely replaced by renewable energy. Renewable energy's still youthful technologies will continuously increase their level of efficiency, and new storage technologies will follow. What matters, by the way, is not so much installed output as the amount of electricity actually produced. Whereas traditional energy technologies tend to be nearing the end of their potential for technological development, so that we can only expect diminishing returns from their optimization, renewable energy technology is at the start of its development, so that each of its varieties harbours a huge potential for optimization.

The speed of introduction for renewable energy also depends, of course, on the cost situation. In every cost comparison between renewable and conventional energy, the basic question has to be whether we are dealing with an isolated microeconomic or with a macroeconomic type of cost accounting (including ecological follow-up costs), and whether this is a short- or long-term calculation. Yet even individual facilities will find that the comparative cost situation is continuously improving in favour of renewable energy when they take a look at its greater potential for innovation. Fixed costs for fuels from traditional power plants, by contrast, can only be expected to rise.

Whoever asks about the amount of time needed to introduce renewable energy will have to compare this time requirement with the time spent on new conventional energy facilities. By way of illustration, between 2000 and 2004, in just five years, Germany experienced the creation of about 14,000 megawatts total capacity for electricity production from renewable energy. Investors had as yet little practice in this new technology, and the power plant industry was not even equipped to handle this kind of growth. Let us imagine, by contrast, that the electricity conglomerates had decided in 2000 to build new large power plants and commenced with the initial preparations. Not a single power plant would have come on line by the year 2004. By contrast, installing solar and wind power facilities took place in a matter of days, and for small water power plants it was only a matter of weeks. In every situation where providing new capacity is the issue, decentralized energy has a clear time advantage. This is especially true for developing countries, because by using the appropriate technologies they can avoid what is not only a costly but also a time-consuming construction of infrastructure (such as for electricity grids) and thereby considerably shorten their pathway to a reliable energy supply.

The thesis that there is an enormously long time requirement for introducing new kinds of energy is a misapprehension that energy experts derived from the history of conventional energy systems. This experience is based not so much on the long construction times required for large power plants as it is on the even more time-consuming process of completing the wide-ranging transportation and distribution structure needed to supply conventional energy. This experience, however, would be applicable to renewable energy only if the choices about its expansion were to be oriented around the traditional model and its trajectory of large-scale technology. Yet, with a few exceptions, this is precisely what renewable energy renders technologically unnecessary and economically meaningless. The fundamental technological-economic assumption behind the excessive time requirement, therefore, is also untenable.

The real time problem for renewable energy is truly neither technological nor economic, but rather political and mental: the political problem takes the form of countless arbitrary administrative hurdles, and the mental problem lies in the need for a change of attitude.

The dispensability of large power plants

The assertion that a secure electricity supply depends in some compelling way on large power plants cannot be maintained if only for the simple reason that there is only one really decisive fact: one can only feed as much electricity into a grid as is taken out of the network. Once electricity is fed into the grid, its origin is no longer physically observable. When grid-based electricity production is decentralized, its geographic dispersion must be broad enough to guarantee a proper voltage balance. But above all, a large power plant is by no means the best guarantee of a more secure and more efficient energy supply. If it breaks down, at one fell swoop there is a danger of large-scale supply interruptions, which can only be avoided by maintaining an extensive reserve capacity. That is the reason why, in Germany for example, only about 60,000 megawatts out of 100,000 megawatts of conventional power plant capacity is used. By contrast, one of the advantages (completely underestimated) of a decentralized application of renewable energy relates precisely to its use of numerous individual modules that operate independently of one another, so that the loss of a few units counts for less. It is therefore possible to do without the extensive reserve capacity needed for a large power plant. Bad planning can also be avoided this way; only when the need for electricity grows are additional modules installed.

The prerequisite for this, however, is achieving a relatively even expansion of electricity production using different forms of renewable energy, so that these can supplement each other reciprocally. Even in order to provide large industrial consumers with power consumption of around a few hundred megawatts, one need not hold on to large power plants if – as emphasized earlier – enough power is fed into the grid from decentralized production. Even a finely meshed supra-regional integrated network is not absolutely required, since each large consumer has the opportunity, should the occasion arise, to switch over to producing its own energy – especially if it has a chance to use combined heat and power cost-effectively or can avail itself in the future of its own storage battery capacity.

In a study for EUROSOLAR, *The German Expansion Potential* *for Renewable Energy in the Electricity Sector*, written by Harry Lehmann and Stefan Peter, the authors refute the electricity conglomerates' assertion that there is an indispensable need, between now and 2020, for conventional large power plants with a total capacity of 40,000 megawatts as a replacement for other large power plants that will have been shut down by then.[19] The study calculates not only how much expansion of capacity will be required for renewable energy, but also the actual compensatory output associated therewith for each power plant. When it comes to wind energy, the study estimates a somewhat reduced additional annual expansion until 2010, which was pegged at around 2500 megawatts in 2003 and will level off between 2010 and 2020 by increments of 2000 megawatts annually. With respect to photovoltaic energy, the study calculates a steep increase until 2010, and after that annual new installations of 1000 megawatts. The same is assumed for biomass, in association with the expansion of CHP facilities, which will increasingly be operating with biomass. When it comes to geothermal electricity production, owing to the time required to set it up using test drills, the assumption is that there will only be a very small expansion up to the year 2010, after which there will be a steep rise (see Table 2).

Table 2 *Capacity expansion for renewable energy in Germany (megawatts)*

Energy source	*Year*	*Capacity expansion*	*Power plant compensatory output*
Wind energy	2010	28,600	4000
	2020	48,600	12,000
PV	2010	10,000	1000
	2020	20,000	3000
Biomass	2010	10,000	18,000
	2020	20,000	
CHP	2010	19,000	
	2020	32,000	32,000
Geothermal	2010	100	
	2020	16,000	16,000
Total in 2020			
Without geothermal			47,000
With geothermal			63,000

Table 3 *Compensatory output from renewable energy (megawatts)*

	Compensatory output via renewable energy	*Compensatory output without renewable energy*	*Compensatory output with 1% gain in efficiency*
2010	23,000	30,000–35,000	23,500–28,500
2020	46,000	40,000–65,000	43,000–48,000

Based on this, power plant output is determined using two variations: one, without any additional gains in efficiency from electricity-consuming appliances, and two, assuming a gain in efficiency of 1 per cent annually (see Table 3).

From this it follows that there is no need to build new conventional large power plants and also no need to extend the lifetime for operating nuclear power plants. Nobody can claim that this possibility is unrealistic from the standpoint of the potential inherent in nature or technology – especially since expanding the use of small water power plants, an equally plausible option, was not even taken into account by this study because it is an option currently crippled by absurd administrative barriers (of which we will have more to say later). Adding this potential, one could paint a picture of renewable energy's prospects that is even more favourable. It also cannot be imputed that this kind of switch to renewable energy would be economically 'unreasonable'. The cost to the electricity consumer would certainly rise, but this will also be the case with new construction for large power plants and as a result of their rising fuel costs.

Let us peer further into the developments the future has in store. The segments of electricity demand as we previously knew them are shifting. On the one hand, the demand for electricity keeps sinking the more that electricity for cooling, heating and warm water in buildings is replaced by solar-thermal energy and CHP, the more energy-efficient electrical appliances become, and the more these devices draw their electricity from integrated PV modules, so that they almost turn into appliances not dependent on electric current. These positive developments in energy efficiency are matched on the other hand, however, by additional demand for electricity in the area of heating and fuel needs, namely via growth in electricity-driven heat pumps. The overall demand for electricity is also going up because of the growing use of information and communication technologies. Electricity is the energy form that has the greatest variety of possible uses; it is, as the Swiss economist and member of parliament Rudolf Rechsteiner says, the 'reference energy' for any consideration of energy systems.[20]

The efficiency advantage of renewable energy

The thesis is that gains in efficiency and savings while continuing to use conventional energy are the most cost-effective and quickest path to lowering energy emissions and should therefore be given priority over mobilizing for renewable energy; however, this is a thesis conceived in isolation, and it construes a contradiction that does not even exist. Greater energy efficiency from motors, electronic devices or houses will function independently of whether one uses fossil/nuclear or renewable energy. The lower the actual demand, the easier it is to substitute renewable for conventional energy because the amount of energy that needs to be replaced in each case is smaller. Any such 'efficiency-based approach' may therefore accelerate the shift in energy from fossil/nuclear to renewable. If the thesis favouring priority for efficiency-oriented strategies refers only to the techniques for energy conversion, it is being imagined in much too simple a fashion. The only thing then being compared is the relationship between the financial input for technically optimizing a conversion facility and the output of energy and emissions. This simple approach neglects everything that happens within an energy flow, from the appropriation of energy to the expenditure of human labour and technologies. One needs to compare supply systems with reference to the entire energy flow and not just its individual elements.

In my book *The Solar Economy* I described in extensive detail the inevitably long supply chains of fossil and nuclear energy use starting with the production of coal, petroleum, natural gas and uranium all the way through to their final use in motors and appliances, and I compared these with the supply chains for renewable energy.[21] The latter are fundamentally shorter simply because –

aside from the use of energy crops – any expenditure to make primary energy available drops out of the picture. Such expenditure can, moreover, be shortened even further (extremely so) if the renewable energy converted in decentralized facilities is also used at the same site or in the same region. Therein lies the systematic advantage of renewable energy, which has not been noticed nearly enough. It has, not least of all, a decisive advantage when it comes to efficiency, and one that has only been exploited in a preliminary way. The advantage is at its greatest whenever a new energy supply system emerges, as in the rural areas of the South, where 2 billion people live without any hook-up to an electricity grid. In this case, one can immediately skip the development that led industrial societies on the path towards ever more centralized energy conversion using large power plants and refineries (and with the sprawling energy supply structure this required).

The kind of autonomous energy that can only be made available to everyone using renewable energy is no makeshift solution; it represents, instead, the general prospect for the future. It gives developing countries an opportunity to get ahead of the game instead of having to undertake a protracted, costly and inefficient effort at copying the energy supply structures handed down from the industrial societies. In industrial societies, the systemic advantage renewable energy has in efficiency terms will only be fully revealed over the medium or long term. This is because the infrastructure expense that was indispensable to produce and supply traditional energy emerged slowly over several decades, has largely been paid off, and only needs partial supplementation, renewal and maintenance. For this reason it is possible to have strategies using this infrastructure – which does not mean this needs to be the standard for every other new approach. All strategic designs for renewable energy need to keep an eye on what constitutes the greatest potential for increasing renewable energy's productivity, which is the opportunity to avoid, whenever possible, the inevitable and wasteful expense associated with making fossil and nuclear energy available. An energy supply system based on renewable energy has efficiency opportunities that are definitively closed off to a system working with nuclear and fossil energy. These opportunities ensue from the following reasons, briefly outlined here:

- Since each instance of 'final energy' use always happens at that decentralized site where people work and live, every decentralized way of providing energy, as a rule, has an efficiency advantage over any centralized solution.
- Efficiency is greater the less technical refurbishing or conversion is required. When fossil energy is used as fuel or heating energy, fewer conversions are required than is the case when fossil energy is turned into electricity, which then has to be distributed. Therefore, proceeding from an input of primary energy, electricity supplied from fossil and nuclear energy in large power plants turns out to be the most inefficient way of making energy available. But since electricity, as emphasized earlier, is the most important 'reference energy', clinging to traditional forms of energy is the greatest obstacle to efficiency in the future of any society or economy. By contrast, the opportunity to turn solar radiation and wind or flowing water and waves into electricity in a single conversion step is tantamount to the greatest revolution in energy efficiency imaginable. The fact that this requires a separate electricity storage expenditure is neither an insurmountable impediment, nor does it reduce renewable energy's systemic advantage.
- If the issue is not the demand for electricity but rather for heating or cooling energy, the direct use of solar heat is the most efficient option imaginable. If the issue is fuel for mobile transportation systems, bio-fuels produced and marketed on a decentralized basis have a clear systemic advantage over hydrogen whenever it requires more technical conversion steps to be made available.
- If, in addition, the direct economic 'secondary effects' are taken into account, the efficiency advantage of a whole range of renewable energy applications becomes even more striking. For example, via the dual function of solar cells and solar collectors as a roof or facade, and the secondary or tertiary utilization of biomass (wood refuse, food leftovers, agricultural waste products) already used for energy elsewhere or of waste products from bio-fuel production (oil cakes for fodder, ashes from biomass gasification as fertilizer, the use of residues from bio-ethanol production for electricity production, and much more).

- By avoiding climate, environmental and health damage and by saving foreign currency when domestic energy is substituted for energy imports, as well as by virtue of the permanent new jobs secured as a result, renewable energy has a higher macroeconomic efficiency that no one can seriously dispute.

Heightening efficiency is both a precondition and a consequence of all rational economic management. Efficiency criteria have to be guaranteed not only when comparing renewable with fossil and nuclear energy, but also when comparing fossil with nuclear energy or different types of fossil energy with each other – and, needless to say, also when comparing different possible uses of renewable energy. Hence, various plans that try to concentrate electricity production from renewable energy and bio-energy on specific regions – on regions where there is more sunshine (for Europe this means North Africa), where the wind gusts are stronger (for Europe this means the European or North African Atlantic coast or on the high seas), where the biomass harvest is larger (as in Brazil), or where more large dams might be built in order to transport energy from there, by way of lengthy transmission lines, to the sites of consumption where, if need be, they can be converted into other forms – such plans are certainly well-intentioned, but they have not been thought through to the end systematically enough. The economic factor of low production costs gets overvalued, and this leads all other factors to get neglected. These are unnecessary attempts at copying on the part of today's energy business. But, above all, it should not be forgotten that the urgent priority of countries that have a large natural potential for renewable energy lies in its use for domestic consumption. Thus, Morocco has one of the most favourable regions for wind in the world – but its energy dependence stands at 95 per cent. By exporting wind-based electricity it will not be able to earn as much as it can save in foreign currency (otherwise spent on imported oil) if it uses the electricity itself. The top priority for using large solar-thermal power plants in North Africa ought to be supplying this region's major cities with electricity – from Rabat, Casablanca, Algiers, Oman, and Tunis, through to Cairo or Alexandria. Only when this is achieved can they also get around to exporting should the occasion arise.

The independence of energy structures in teamwork

Centralized structures for supplying energy did not arise because they were more 'economical'. The real reason was that transporting electricity is something that can be done substantially faster and cleaner than moving fuel. This counts for a great deal, above all, when it comes to supplying cities with energy. In order to understand why, one needs to know the history of electricity supply.

At the beginning of electrification there were two different basic concepts represented by two pioneers that led to an entrepreneurial conflict that both sides fought with bare fists. It was the conflict between Edison and Westinghouse. Edison's vision was that of producing electricity on one's own – in other words, self-supply – in every house, while Westinghouse's idea was to provide electricity to houses via transmission lines. The latter had – under then-current conditions of electricity production using fossil fuels and water power – a better 'systemic' outlook. Electricity from water power cannot be produced in cities; it is only usable via electric transmission lines. These can supply electricity quickly and cleanly into the home. Edison's plan, by contrast, required delivering fossil fuels into every house, with the result that there would be numerous individual fireplaces in the city, which people were already fed up with because of their experience with heating from coal. His plan was, to be sure, more liberal, but for city dwellers it promised more immediate environmental damage and less comfort.

The conditions that led to the model of a uniformly networked energy supply using large power plants as production centres tend to become invalid, however, when renewable energy enters the picture: using solar energy for someone's own decentralized electricity production does not now require fuel transport. 'Delivering' sun rays happens all by itself and costs nothing. In addition, there are opportunities to make electricity from bio-gas and cities' own extensive food leftovers, as well as to produce electricity from wind power and biomass in urban environs and rural areas. Even if this takes place within an electricity cooperative network, no wide-ranging transmission networks will be needed. On the contrary, the more that decentralized electricity production and supply takes hold and spreads, the less need there will be to use existing networks to capacity. The costs for grid users will therefore rise when the network – within the framework of a liberalization that is fair to all market participants – is no longer co-financed by those who no longer use the grid (or who use it only part of the time). This will motivate many to switch over to decentralized production and marketing. The traditional system will lose its former economic edge. Electricity production will fragment. In addition to electricity that is supplied by a network, there will be decentralized production for the individual's own needs and for neighbourhood demand, area supplies for housing estates, insular supplies for smaller cities, either wholly autonomous or supplemented by spot transmissions. Supplying electricity will return – not fully and immediately, but increasingly – to the vision of its pioneer Edison, a vision that is only practicable on the basis of renewable energy.

How this process takes shape will depend on external factors (legislation), sociological factors (information, level of education, cultural and values consciousness), and technological factors. In order for the opportunities and limits of energy systems to be analysed and evaluated, however, one fundamental insight needs to be considered that is usually ignored: the most formative influence on an energy system is the energy source used. Whatever source is chosen first determines which techniques of energy production and conversion become indispensable, as well as, second, which infrastructure requirements actually exist, along with, third, the corresponding entrepreneurial forms that emerge. The widespread notion that the structure that arose for conventional energy is the standard for modern energy provision, and would therefore also be the best yardstick for renewable energy, is mistaken. This misconception sets in at the third stage in the development of an energy system – today's structures – in other words, after the first step – the choice of an energy source – and after the second, that of the technology that is necessary and possible for that source's productive utilization.

If this sequence is not recognized, today's structure will appear as if it is a sacrosanct and objective requirement setting narrow limits on the expansion of solar- and wind-based electricity. The central rationale behind this restrictive objection is the assertion that energy from solar radiation and wind cannot be stored. If no sun shines on the solar facilities and no wind blows on the rotors, fossil power plants would have to be on hand for constant reserve duty. That means they would literally have to be constantly 'under steam' so that they could jump in at a moment's notice. This would actually reduce the positive environmental impact of solar and wind power facilities, and it would cause pointless expense. These added costs (the argument runs) would become higher in proportion to how many more solar and wind power facilities would be attached to the network, especially if the electricity business were forced by arbitrary political decisions to store this current. This thesis is a key argument that many people found convincing during the campaign against Germany's Renewable Energy Sources Act.

Storing sun and wind power

Energy storage is always necessary when there is no simultaneity between the production and utilization of energy. In a strongly centralized and internationalized nuclear/fossil energy supply system, this simultaneity is, on principle, not possible. The storage warehouse for petroleum is the oil tanker, for coal it is the coal heap, for natural gas the major storage caverns and the gas tank, for nuclear energy the fuel rod store, and for water power (if necessary) the reservoir. Transport and distribution systems – pipelines, tanker ships and trucks – take on a supplementary storage function. Or else it is the power plants themselves that operate as steam power plants, that is, they produce steam, which they must then keep holding inside the power plants as a reserve in case there is a rapid increase in production. All nuclear power plants and all large fossil power plants are of this type.

In the current energy system, energy is stored prior to its conversion into electricity or heat. When it comes to renewable energy, this is also possible in the case of dammed-up water power and bio-energy. Geothermal energy even has the most perfect of all storage warehouses, namely the Earth itself, directly underneath the power plant. Otherwise this is possible only with natural gas, if the power plant has been installed directly above the production site. With energy from solar radiation and with power from wind, waves and un-dammed water, by contrast, it is not possible to store energy prior to its conversion into electricity or heat. These other forms of renewable energy need to be stored after conversion; that is the essential difference.

In any event, conventional power plants – independently of whether there is or is not any solar- or wind-based electricity in the network – need to be on constant standby to produce electricity so they can react to continuous fluctuations in electricity demand. This is the reason their energy consumption is inefficient. If feeding solar- and wind-based electricity into the grid does not achieve an order of magnitude conventional power plants must have simply in order to stand ready with a reserve that is uneconomical and unecological, this is no convincing reason to limit the expansion of renewable energy. The obvious step to be taken should be shutting down the entire operation of these conventional power plants and then organizing the reserve potential for solar- and wind-based electricity using other forms of renewable energy – such as biomass, water power and newly installed storage capacity. It is dissembling amateurishness for the electricity business to dispute these possibilities.

In its campaign against renewable energy, the energy business never mentions its own storage capacity, as if this were not just as easily usable as a reserve for solar- and wind-based electricity, for example, water power from dams, pump storage stations or frequencies available within the electricity grid. The possibility that the sun might not be shining or the wind might stop blowing just when these sources are most needed to produce electricity is presented as an insurmountable obstacle – as if, by way of contrast, extra coal or uranium could be hauled out of the mines at the very moment there is a spike in demand for coal- or nuclear-based electricity. Although the storage problem for solar- and wind-based electricity is exaggerated, it is necessary to devote more attention to it than has previously been done. Not every country can count on having laws that facilitate feeding this kind of electricity into the supply network without obstructions and in an economically attractive way, and one-third of the world's population lives without any hook-up to an electricity grid. In cases like these, both a general willingness to reorient electricity generally around the sun and wind as well as solar- and wind-based electricity's expansion depend on available services for reserves and storage.

An additional reason is that political setbacks are imaginable even in those countries where feeding the networks with electricity from renewable energy is currently guaranteed by law. Solar and wind power plants that have a plant-related reserve and storage capacity make it possible to overcome not only dependence on traditional structures but also widespread prejudices on this subject. The supply side-oriented approach to dispensing electricity from renewable energy can be supplemented by a demand side-oriented approach, which will substantially improve its profitability. The frailty of large power plants with their inefficient 'steam generators' will finally become apparent for all to see. From just a few supply structures exercising wide-ranging control over vast transregional and transnational grids there might emerge a great many small-scale supply structures. Opportunities for self-provision of electricity will multiply – extending all the way into private homes and even reaching as far as the countless electrical consumer appliances ('stand-by' or 'stand-alone' systems) that can produce their own electricity, either wholly or partially, using integrated PV modules. As it is, these devices already constitute 15 per cent of total electricity consumption – and this is a growing trend because of new information technologies, from mobile telephones to the notebook computer. Departing from the previous century's trajectory of supplying energy first in kilowatts and ultimately in gigawatts, a pathway that turned into a very broad one-way street, there will emerge a variety of pathways supplying energy first in gigawatts, then in megawatts, kilowatts and milliwatts.

It would go beyond the scope of this book to introduce the spectrum of storage variations and their respective fields of application. They range from new batteries – Toshiba has just introduced one that can be charged in three minutes – to flywheels, compressed air, hydrogen or thermo-chemical storage devices. They were introduced in the chapter 'Energy beyond the grid' from my book *The Solar Economy*.[22] Richard Baxter offers a comprehensive account of storage methods already in use in his book *Energy Storage: A Non-Technical Guide*.[23] In general, one can say that these become cost-efficient from the moment at which storage costs less than the energy delivered. Investments in storage capacity even begin to suggest themselves under conditions of conventional energy supply, so that it becomes possible to make substitutions for expensive deliveries of electricity at peak hours.

One practical way to have an independent 'island network system' has been demonstrated by the German wind power producer Enercon since 2004 on the Norwegian island of Utsira. Its point of departure was the local system of energy supply using diesel generators within the island's network cooperative. The alternative realized by Enercon is based on wind power plants, supplemented by a synchronous machine for regulating the line voltage and using a flywheel for short-term storage and batteries for long-range storage. The diesel generator now only needs to be used at just 10 per cent of its capacity – and its fuel needs for this lower usage can easily be met with biomass. At the same time there are tests going on – in case a substitute is needed – for a hydrogen generator in which the hydrogen is likewise produced from the wind power plant's electric current. The entire system guarantees a comprehensive, round-the-clock supply of electricity from renewable energy.

Increasingly, storage in the form of compressed air is gaining attention. Smaller amounts can be stored in compressed air containers. With compressed air receptacles – each about the size of a 10 cubic metre container – it is possible for homes to have their electricity supplied non-stop and autonomously on the basis of a PV system. A practical example of large compressed air storage is the Huntorf power plant in the German state of Lower Saxony, which has been in operation since 1978 with a capacity of 290 megawatts. Storage takes place in two ground caverns at a depth of 650 and 800 metres with a total volume of 300,000 cubic metres. At times when there is a surplus of electric current, air at a pressure of 50–70 bars is pumped into the caverns. These can be filled to the brim within eight hours. The compressed air power plant can be started quickly and reach

50 per cent of its maximum performance within three minutes. Another example is the 100-megawatt power plant in McIntosh, Alabama, which has been in operation since 1991. The compressed air is stored in several caverns with a total volume of 538,000 cubic metres. It operates at full performance for 26 hours. In both instances, it is fossil- or nuclear-based electricity that is stored, but their storage potential could just as easily be used for wind-based electricity. Some new compressed air storage facilities have made wind-based power their point of reference from the outset. The Iowa Stored Energy Project, which is allocating 84 megawatts of wind power for a 200-megawatt compressed air power plant, and using an aquifer 400 metres underground that previously served to store gas. In McCamey, Texas, there is a 400-megawatt compressed air power plant, which is fed by 270 megawatts of wind power capacity and can produce 10,000 megawatts hours of electricity with a storage filling. It can furnish 37 hours of maximum performance. The number of caverns and aquifers that can be opened up is considerable and developing them would require a one-time investment. They fulfil the same function as pump storage works in which water gets pumped into artificial or higher-filled natural basins in order to produce electricity again.

Think about the many mountainous Greek islands that could organize their entire energy and water supply solely from wind energy. Wind power plants produce electricity for the inhabitants' direct consumption, for the operation of a seawater desalination plant, and for pumping this water into a storage basin. The latter, in turn, fulfils three functions: providing fresh water to the island's inhabitants, agricultural irrigation, and producing electricity to complement the wind power plant. Together with solar collectors and bio-fuels – produced from the leftovers of agricultural production that has been revitalized by freshwater irrigation and from food – this island would become energy-autarchic. Once the island was set up with this kind of installation, no energy bill will ever have to paid again to anyone outside the island.

What is possible on natural islands is, however, also possible in 'insular structures' – and this is even the case on a larger, indeed a very large, scale. Norway has so much water power from dams that its electricity needs are completely covered this way. This electric current is exportable via transnational transmission cables; the resulting shortage for purposes of domestic consumption is meant to be covered by gas power plants. But why not, as an alternative, use wind power plants along Norway's wind-rich fjords? Combining wind and water power alone should be enough to facilitate a functioning electricity supply system, one in which sufficient water power and an extensive electricity grid would be available. This is an opportunity that is available in numerous large regions inside Europe – in the Alpine countries or the Balkans, in addition to Scandinavia. The opportunity exists in Brazil, China, Canada, Ukraine, Japan, Central Asia, in large sections of Russia, India and the US – even if no additional renewable energy options were to be brought into play. China, for example, has 200,000 megawatts from coal-fired power plants and 100,000 megawatts from hydroelectric power plants on dams and, according to current plans, it intends to rush ahead with the additional construction of 70,000 megawatts for water power, 150,000 megawatts for coal-based power, and 30,000 megawatts for nuclear power. But it has a water problem in the big cities of the interior that is getting worse, a problem that is attributable not least of all to the enormous water consumption demanded by coal mining and power plants, and which is going to get even worse with more nuclear power plants. By replacing coal power plants with wind power, for which water power plants would provide compensatory storage, it might be possible within a short period of time to arrive at an emissions-free electricity supply. This immediate opportunity exists in countries with large water power plants that have already been installed and with extensive electricity grids. Just the combination of wind and water power from dams alone, in any event, makes it possible to have an energy supply available around the clock.

Bio-fuels and new drive-assembly technologies

Petrol, diesel and kerosene (for jet planes) represent 95 per cent of all the transportation fuels used worldwide today. For nearly a century, motor technology – whether for vehicles moving on land, air or water, or for stationery use – came to be increasingly oriented around combustion engines using petroleum derivatives. This did not happen for lack of other drive technologies; at the beginning of the 20th century there were electric motors with the same efficiency as combustion engines, and these were also used for decades – like the delivery vehicle Opel Blitz or the city bus systems hooked up to electric power lines (overhead cable or trolley buses). Even Henry Ford's original idea about the 'automobile for everyone' involved powering the vehicle with bio-ethanol. That there can be alternatives to petroleum is proven by the vehicles operated in Germany during the Second World War using wood gasification motors, and by the Red Army's off-road vehicles in the former Soviet Union, which were able to work using pure vegetable oil. A diesel motor developed by the German car engineer Ludwig Elsbett that runs on pure vegetable oil has existed for decades, yet not one of the major car manufacturers has tried to put it on the market.

What emerged over the course of the last century was a total fixation on petroleum fuels in a period of cheap oil without competition, the era of unrivalled petroleum that edged out all other fuel options during the first few decades of the 20th century. The petroleum business programmed the development of drive technologies accordingly. It was a business that expanded into the world's last isolated hamlet and acquired a unique global monopoly. This also made it even easier for oil to conquer the market for heating fuel. The car industry – which cannot sell even a single car without there being fuel for purchase – had to adjust the development of its motors to petroleum fuels. Even environmental policy had to do this later on, when it came to setting standards for improving fuel quality and reducing pollutants. The result of all this was a monolithic structure fixated on fossil fuels.

The problem with bio-fuels is not only that – apart from Brazil and with the partial exception of the US – there is still insufficient bulk production to entice the car industry into offering suitable motors for them everywhere. In addition, so long as specific drive technologies are required for each one of the different bio-fuel options – vegetable oil, bio-ethanol or sunfuel – this problem of a low level of interest on the part of car manufacturers will remain. The car industry thinks in terms of producing large series – that is, apart from the prestige cars each manufacturer uses to cultivate its brand name. It was only when some diesel vehicles were first cleared for esterified vegetable oil use in Germany that there was finally a bit of market development. An additional obstacle is the petroleum industry, which sees its supply monopoly endangered by bio-fuels and wants to keep them at arm's length for as long as possible. Yet another obstacle has more of a social character, and this impediment is one that reaches all the way into the environmental movement: it is the notion that expanding the use of biomass will entail extensive competition with food production and nature reserves, and that this might intensify the trend to monocultures in agriculture. These misgivings are seized on by the petroleum industry – though the same apprehensions have hardly inhibited the oil business from swamping farms worldwide with petrochemical fertilizers and pesticides and from increasingly burdening the ecosphere with a growing supply of fossil fuels.

It is price that is regarded as the biggest obstacle. Yet the price barrier is the easiest hurdle to clear through a tax exemption for all bio-fuels, which has recently become the rule in Germany, Sweden, Spain and Switzerland. As a result, bio-fuels have already become cheaper than fossil fuels in those countries. Governments, of course, lose tax revenue this way. But in return they take in other taxes, because the production of bio-fuels leads to the creation of new jobs – and that means saving money on welfare transfers for people who had been unemployed – while simultaneously stabilizing the social consensus between business and labour owing to the additional employment effect. The way to dispel ecological misgivings about bio-fuels is to use production and marketing plans that, instead of mindlessly increasing bulk production in giant plantations, rely on multi-cultivation and multiple reuse of raw and residual materials. It is obvious, moreover, that there is an urgent need for a discourse about arranging ecological dangers in some kind of hierarchal order, a subject we shall deal with in Part II. The technological dynamic whereby the obstacles mentioned can be overcome in the vehicle and fuels markets, however, requires a reversal of the previous paradigm for motor manufacture. Instead of adjusting motors to fit one particular fuel, they should be geared to work with several different fuels and the possibility of a flexible mix.

The 'flexible fuel' car that has been put on the market at no extra charge by all the major car producers in Brazil since 2004 fits into the category of essential new drive technologies. The catchword is the multi-fuel engine. Bio-ethanol can be added to become up to 85 per cent of the fuel mix, and 100 per cent is a technological option within reach. The proportions of the mixture can be determined by the driver anew every day; a meter displays the proportion in the mixture at any given time. If bio-ethanol is not offered at the filling station, it can be fetched from a special supplier. The petroleum business loses its monopoly. In order not to keep losing market share, it will begin to offer these fuels itself. A flexible variant of this kind is the Elsbett motor, which takes pure vegetable oil in addition to diesel fuel. The 'sunfuel' developed by the German chemical engineer Bodo Wolf and his firm CHOREN – which can be produced from solid biomass using high temperature gasification, so that a fuel with a diesel-like quality is produced – accommodates the car manufacturers' previous paradigm. Yet it would be a mistake for the car industry to insist on a single fuel – even if it is made out of biomass. The future lies in a mixture of bio-fuels, so as not to dictate one single route for using bio-fuels to every region in the world. Only if this route is not pre-ordained one-sidedly by this or that motor technology can the whole potential of bio-fuels be fully developed, based on a variety of ecologically compatible cultivation plans, and only then can the car industry keep producing cars in large series. This process will also be accelerated by hybrid drive technologies that reduce actual fuel needs through electricity produced in the vehicle itself.

The macroeconomic advantages

Its purported indispensability is what obtains a special political, economic and social position for the established energy business. This is how it validates its monopoly not only on competence but on action as well. Yet the energy business is hardly the only business capable of making the investments needed to supply energy. It is indeed barely conceivable that financing a comprehensive and effective mobilization of renewable energy would take place within the confines of the traditional energy business with its highly concentrated and interlocking structures. No company pursues its own loss of sales and therewith its own decapitalization. But in this case, one has to hazard the consequences. Taking this risk is the price of any wide-scale structural change. The world of renewable energy, with its decentralized usage, is no place for a monopoly of investment and operations. There are plenty of potential investors, and consequently there are also no limits on the financial resources that can be mobilized on behalf of renewable energy.

Even the counter-argument that introducing renewable energy entails a major economic burden is only correct if microeconomic burdens are equated with macroeconomic ones and if nobody distinguishes between short- and long-term burdens. Undoubtedly, the shift to renewable energy is a burden on the energy business, a burden that is greater the quicker and the more broadly the transformation takes place. For many actors, especially in the primary energy sector, this prospect poses an existential threat. Even energy consumers might be in for some temporary burdens. But to avoid them means to hazard even greater burdens in the future, because ultimately no one is spared the wildfires of the global crises caused by energy. Seen from a macroeconomic perspective, by contrast, the shift to renewable energy presents an enormous opportunity. Taking advantage of this opportunity, however, means recognizing new ways to proceed. Instead of simply extrapolating from the large-scale to the small-scale, one needs to see how the small-scale points to the big picture.

The macroeconomic advantages of renewable energy reside:

- in its indigenous availability and thereby in the currency savings it affords along with the improvement in the balance of payments from cutting back on energy imports;
- in the replacement of commercial fuels by free primary energy, that is, in the substitution of technology for fuel

costs – and thereby in the creation of new jobs for installing power facilities. Unlike large power plant construction, which cannot be distributed broadly enough, production of decentralized power facilities is possible in almost every country;

- in the avoidance of infrastructure costs through regionalized energy production that is then used in the same region;
- in the promotion of crafts and agriculture that comes from solar construction and biomass utilization, which means permanent stabilization of small- and medium-sized businesses and thereby of regional economic structures;
- in the broad distribution of income because of the emergence of decentralized entrepreneurial forms;
- in the avoidance of ecological follow-up costs, inter alia by reducing health costs and costs for catastrophe prevention and compensation;
- in the avoidance of international security costs (see Table 4).

Waiting for Godot: Fossil and nuclear autism

The sponsors of the traditional energy system would prefer to carry on the same old way. They are in a unique position. They are pulling all the strings. Without the fossil energy business (as the people running this sector see things, based on their inveterate self-image), industrial society as it developed over the last 200 years would never even have existed, and our modern economy and society would simply have collapsed. For the economist Elmar Altvater, the industrial era is more accurately described as 'fossilist' than, say, 'Taylorist' or 'Fordist'.[24] Even more tellingly, the fossil era held its ground and emerged even stronger over the last 30 years, a time when sociologists had proclaimed the 'post-industrial era'. And the energy system's spokesmen now herald even more growth in fossil energy consumption, although others are already talking about the 'de-materialization of the economy' and the 'information' or 'digital age'.

But how would the history of the last two centuries have turned out if James Watt had not invented a steam engine for

Table 4 *The macroeconomic advantages of renewable energy compared to fossil and nuclear energy supply*

	Fossil	*Nuclear*	*Solar electricity*	*Wind electricity*	*Small-scale hydraulic power*
Domestic availability, currency savings and improvement of balance of payments because of energy imports avoided	No or limited	No or limited	Yes	Yes	Yes, with appropriate topology
Creating new jobs by producing own plants	No or limited	No or limited	Yes	Yes	Yes
Increasing productivity by avoiding commercial fuel costs	No	No	Yes	Yes	Yes
Increasing productivity by having fewer conversion steps	No	No	Yes	Yes	Yes
Avoiding infrastructure costs (transmission, transport, distribution)	No	No	Yes	Yes, except with offshore	Yes
Promoting decentralized economic forms (agriculture, skilled crafts)	No	No	Yes	Yes	Yes
Promoting growth through private investment, spreading ownership	No	No	Yes	Yes	Yes
Reducing climate damage	No	Minor	Yes	Yes	Yes
Reducing health damage	No	No	Yes	Yes	Yes
Safeguarding water	No	No	Yes	Yes	Yes
Avoiding security costs	No	No	Yes	Yes	Yes

	Large hydraulic power	*Waves*	*Solar-thermal electricity*	*Solar heating and cooling*	*Geothermal*	*Energy plants*	*Residual biological materials*
	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	No	Yes	Yes	Yes	Yes	Yes	Yes
	Yes	Yes	Yes	Yes	Yes	No	Yes
	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	No	No	No	Yes	Dependent on plant size	Yes	Yes
	No	Yes	No	Yes	Dependent on plant size	Yes	Yes
	No	Dependent on plant size	Dependent on plant size	Yes	Dependent on plant size	Yes	Yes
	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Yes	Yes	Yes	Yes	Yes	Dependent on use of modern technology	Yes
	Possibly	Yes	Yes	Yes	Yes	Dependent on cultivation plan	Yes
	Possibly	Yes	Yes	Yes	Yes	Yes	Yes

which coal was the most suitable energy supplier? What if, instead, he had come up with a solar-powered steam engine driven by a parabolic mirror (the forerunner of the modern parabolic dish collector), like the one presented at the Paris World Exhibition in 1878 – about 100 years later – by the Frenchman Augustin Mouchot? This machine was the sensation of the fair and aroused enormous interest, especially since France had just experienced supply shortfalls in coal. But new coal-mining technologies became available immediately after the exhibition, and the bottleneck became a thing of the past. Mouchot was forgotten, along with his 1869 book *Solar Heat and its Industrial Applications*; his solar steam machine can be seen today at a technology museum in Paris.[25] The machine did not stand a chance of being introduced into the market even though at that time people were not so small-minded and condescending as they are today, always checking to see if a new technology will 'pay off' from the start. Yet the coal-driven steam machine, the energy transformer of the 19th century – deployed in factories, steam power plants, in ships and locomotives – had already made itself so indispensable that a power structure quickly emerged from the coal economy and from the producers and users of the corresponding technology. A power structure like this does not give up the ghost simply because a better technology might fulfil the same goal in a different way. Rather, such a power structure is more likely to play off its lead, the advantage in technical maturity it acquired over several decades, and its influential political networking against anything new and different that it cannot control.

Like any other system, the energy system also strives for self-preservation. The more self-confident and powerful it is, the more effectively it acts. And what could convey greater self-confidence than identifying with the great success story of the Industrial Age (whose tale of woe, of suffering and misery, is hardly ever related in the same breath as the triumphalist narrative)? Electrical workers were regarded fairly early in the industrial era as the 'new masters of the world' – thus the title of a publication by the physicist Felix Auerbach from 1901.[26] And Lenin's famous sentence, 'Communism is Soviet power plus the electrification of the whole country', was matched in the

West by the writer Victor Hugo's statement that democracy equalled the general franchise plus electricity. The all-embracing role of the steam engine was ultimately focused on producing electricity. Down to this very day, steam engines drive the turbines of large nuclear and fossil power plants. The second key energy transformer was the combustion engine, which gave the petroleum industry of the 20th century its major impetus and turned oil into the vital elixir of the world economy.

Thus (and especially since the world's energy needs keep growing), it is outside the realm of the imaginable for the current system's sponsors to grasp that the energy they are supplying does more bad than good – and that renewable energy might take the place of fossil and nuclear energy. Society, too, can no longer just mentally dismiss today's energy business. At best the role of renewable energy is seen as one of satisfying the extra demand that cannot any longer be covered by nuclear and fossil energy. Finding a substitute for the latter, by contrast, is subject to a taboo. That is why even those 'scenarios' put out by the world's energy conglomerates and regarded as especially far-reaching stop short of envisioning this substitution. These are the ones put out by BP and Shell, scenarios that garnered enormous applause from the environmental scene over the last few years and were also frequently cited at renewable energy conferences: renewable energy can – according to what these studies say – meet half the world's energy needs by 2050. The assumption underlying this prognosis, however, is that world energy demand will have doubled by then. In plain language this also means that the core of conventional energy supply will not be shaken up in any way. For internal consumption within the company, the anonymous author of the Shell study had calculated a 100 per cent scenario, but he was given to understand by the corporation that it could not accept such a statement.

The economic pacemakers for renewable energy – leaving aside, as always, the big hydraulic power plants – are not the conglomerates that support the conventional energy system, but rather local and municipal energy companies that have stepped out of line, small technology companies and investor groups. One might object that this is typical for the pioneering phase of any industry, before the sturdy and experienced workhorses inevitably arrive on the scene. This is how the 'roll-back' in the US that was discussed in the Introduction got started. Has everything become different all of a sudden because energy-based crises are on everyone's mind and renewable energy is now within reach? In spite of all the forces of resistance just mentioned, can we now really expect to see more and more of the concrete walls blocking renewable energy start to crumble? There is much more evidence speaking against than for the possibility of the big energy conglomerates now becoming the driving force behind renewable energy. More and more oil drills and production licences need to be amortized. Pipelines, large power plants, refineries and grids need to be used to capacity. Investments in large power plants and infrastructure have amortization periods lasting two to three decades. The different individual investments for each never occur at the same time. The number of major investments that are prefinanced is always roughly as high as the number of those that are depreciated. There is, accordingly, never a good time to flag down a travelling train and transfer to another one. At best it should suffice occasionally to uncouple one wagon and attach a new one.

The real calculation the energy conglomerates are making is different from the one they are presenting to the public. They simply do not want to admit this, which is what makes the energy debate so dishonest. To be sure, the system will continue to crumble because of ongoing energy-based crises. There will continue to be occasional openings towards renewable energy the more it is recognized that there is no stopping this new train. If one goes along for the ride, one can always, if need be, put the brakes on, turn around or travel on two different tracks. Some people will cooperate for reasons of public legitimacy, since totally abstaining from renewable energy can no longer be publicly justified. Be that as it may, this is no way for renewable energy to achieve a timely breakthrough. In the future, too, no one can expect a move to put renewable energy in the conductor's seat to come from the conventional energy system. Renewable energy will not be handed that locomotive role, that is, unless we lower our expectations and are satisfied taking a slow train.

And, in any event, there is a hard core that keeps pursuing the ongoing triumphal march of the nuclear and fossil energy system. This has been articulated, crystal clear, in the national energy report of the US from 2001, under the aegis of Vice-President Cheney. They are planning oil drills on nature preserves, large-scale dredging of oil sands, methane hydrate from the ocean as a successor to natural gas, new coal and oil production techniques in order to do a better job exploiting available reserves, new nuclear power plants, promotion of nuclear hydrogen, new transmission lines in the tens of thousands, and military protection for international energy resources.[27] Internationally the Bush administration is actually less isolated than it appears as a result of its refusal to ratify the Kyoto Protocol. What was discussed in 2004 at the nuclear conferences in Moscow broadly corresponds to the nuclear portion of the Bush-Cheney programme, and to the view held by Russia, Japan, China, India, EURATOM and sections of the EU Commission. The 'fossil' portion of the Bush-Cheney programme is broadly coterminous with the World Energy Outlook of the IEA and the statements of the 2004 World Energy Conference in Sydney. And as far as the military safeguarding of energy resources is concerned, UK as well as US practice is in line with the Bush-Cheney report, and the EU's security policy in its most recent formulation comes even closer to this line of thinking.

This autistic attempt at self-preservation, however, needs to be legitimized against a background of very public climate dangers. The catchword abused for this purpose is 'sustainability'. In the 42-sentence final declaration of the Sydney World Energy Conference, which declares that growth in fossil energy consumption through 2050 is unavoidable, the concept crops up ten times. It is apparent that the established energy system has regrouped. The plans they are following are formulated in such a way that they promise a way out of the world's climate traps without shifting to renewable energy. An attempt is being made to acquire conceptual sovereignty in responding to the world's climate dangers. The effort includes an official avowal of faith in the Kyoto Protocol. The thing that everyone finds disturbing about the attitude of the US government is its official rejection of this treaty. The plans and concepts brought into play against forcing the issue of renewable energy are an intensified argument in favour of natural gas, 'clean coal' power plants, large-scale plans for hydrogen, and – in a close though often only cautiously articulated association therewith – a renaissance of nuclear energy. In no way can a single one of these plans stand comparison with the opportunities renewable energy offers. The advocates of these last-ditch survival strategies for fossil and nuclear energy resemble the characters Vladimir and Estragon from Samuel Beckett's *Waiting for Godot* – two vaudeville figures lost in time and waiting in vain for someone they do not know and who possibly does not even exist.

Natural gas – a bridge to renewable energy?

Word has got around that petroleum reserves are expected to run out within the first half of this century. Denials of this realization keep getting toned down. Yet with new drilling and production techniques available, an unflagging attempt is being made to eke out from the ground even more of whatever promises to become economically attractive as soon as easily extracted petroleum deposits get scarcer and thereby more expensive. These, then, are the 'non-conventional' reserves: Arctic oil, deep sea oil, or simply what can be found in oil sands and slate. Fifty years ago even North Sea oil still had a reputation as 'non-conventional'. But since nobody could claim that these reserves might be portrayed as climate-friendly, there is now more talk about natural gas, as if this could be treated as a form of renewable energy. Because burning natural gas creates significantly less in the way of direct environmental pollution, it is also on the list of priorities drawn up by many environmental policy makers and scientists. Natural gas is even praised as a 'bridge' to the era of solar hydrogen, as renewable energy's natural partner. The natural gas networks of today as the hydrogen networks of tomorrow! As if it were now already self-evident that hydrogen is going to be the next step. And (furthermore) as if future production facilities for hydrogen could be installed exactly at those sites where gas is fed into the network today. This is how one kind of future for renewable energy is being solidly (mis)planned – a future that, in all probability, will have to look quite different.

It is certainly understandable that natural gas should be preferred to any of the other fossil fuels, especially in cities. Natural gas does significantly reduce current air pollution. In New Delhi this became immediately tangible as a matter of sight, sense and smell ever since the public bus system there converted to natural gas. Natural gas, moreover, is well-suited for combined heat and power cogeneration, and the efficiency of large power plants using natural gas is greater than when they use coal or oil. Building costs are lower and construction times shorter. But all these facts do not justify dismissing the grave problems that either relativize the advantages, both ecological and economic, of natural gas or negate these benefits entirely. Above all, in almost every discussion about natural gas the climate dangers are hushed up even though it is indisputable that a natural gas molecule has a climate-changing impact 20 to 30 times greater than a carbon dioxide molecule. A byproduct of extracting and transporting natural gas is a higher level of methane emissions. The precise order of magnitude is not known and probably also not registered. Some say that the Russian gas network, from which more than a third of Europe's gas supply comes, emits massive amounts of methane owing to leaks. This was denied in a study conducted by the Wuppertal Institute for Germany's largest natural gas supplier, Ruhrgas.[28] But the Institute certainly did not have its analysts pace off the many thousands of kilometres that make up that gas network. It can be neither confirmed nor denied that methane's contribution to rapid climate change over the last several years might be greater than previously assumed.

When people talk about the efficiency of natural gas, they should also look at the energy losses that go along with transporting it, for example, at all the pumping stations. Even greater are the losses that take place when natural gas has to be transported not across pipelines but in fluid form (liquid natural gas or LNG) on ships. These losses happen because the technology for LNG requires cooling temperatures as low as –160°C. The trend, however, is increasingly running in the direction of LNG because the expense of using pipelines over long distances only pays off after natural gas has been extracted from a 'giant field'. Transport opportunities for LNG are considerably more flexible than they are for pipelines, and this factor becomes more important the more that production and consumption expand. Natural gas is also running out, along a time line roughly parallel to petroleum, as Julian Darley has calculated in his book *High Noon for Natural Gas*.[29] How quickly it can run out (and how expensive it is to hire experts who assert the opposite) can be shown in the US, which since the 1990s has achieved a massive expansion of gas power plants with a total of 220,000 megawatts and now faces the problem that there is not enough natural gas available to have these new plants working at capacity.

Those countries and regions that have significant natural gas deposits are just as limited as those having petroleum deposits, and the two areas are largely coterminous. Essentially, these are the North African countries of Egypt, Algeria and Libya, plus Nigeria, Russia, the countries of the Caucasus or Central Asia, Iran and the Gulf state Qatar. Among two-thirds of gas producers, rates of production have already started to slow down. For this reason more and more countries are becoming interested in the increasingly scarce potential of Russia and the Central Asian countries. In addition to the EU, the countries lining up to exploit this shrinking supply include the US, Japan, China, Korea and India. The increasing bias of energy investments towards natural gas, investments that constitute a disproportionate share of the US$16 trillion the IEA regards as indispensable through to 2030, is therefore an orientation that clearly clashes with anticipated supplies. It is hard to see how the projected increase in worldwide demand, from about 200 billion cubic metres per annum currently to around 300 billion cubic metres by 2025, can still be satisfied.

The upshot could be that people will lose their inhibitions and become more inclined to fall for what might prove to be the world's most dangerous environmental adventure: exploiting gas hydrates above the sea floor – the 'fire from the ice', as Hans Schuh titled an article in the German weekly *Die Zeit*.[30] This oceanic hydrate developed from the putrefaction of algae and plankton. Under high water pressure and ice-cold temperatures, most of this potent mix was transformed over long stretches of time into gas hydrates that got deposited on the ocean floor instead of ascending into the atmosphere above the water surface. One litre of this hydrate contains 164 litres of methane gas. There are estimates promising volumes of gas from the ocean depths and permafrost regions of Alaska, Canada or Siberia that amount to double the entire reserves of petroleum, natural gas or coal, 12 trillion tons of carbon. That is mind-boggling. More cautious estimates – like those of geophysicist Alexei Milkov in *Earth-Science Reviews* – mention 'only' 500 to 2500 billion metric tons.[31] Perhaps this more sober figure will put a brake on the gas hydrate intoxication. For the dangers inherent in drilling are incalculable.

The gas hydrates, whose deposits are supposed to have an elevation of 1000 metres on some ocean floors, contribute to stabilizing the continental slopes. If they are broken down, there is a danger that oceanic mountains in the deep sea will collapse, on a scale as incredible as a tsunami. Geophysicists suspect that about 8000 years ago methane hydrate was released between Iceland and Greenland because of ocean water warming up, resulting in more than 5600 cubic metres of the continental shelf collapsing into the Atlantic (the 'Storrega slide'). This was how the Norwegian fjords arose, which gives one an idea of the kind of power this flood released. Gas hydrates could, at a minimum, raise the dangers confronting the globe's climate to a much higher degree:

- extracting gas hydrates, whether in the ocean or in permafrost regions, is hardly controllable overall and can lead to massive increases of methane escaping into the atmosphere;
- ocean warming resulting from carbon dioxide emissions could lead to a change of direction in the Gulf Stream's flow (an event long dreaded anyway) so virulent that this potential becomes like a tsunami – wherever that might be.

Nevertheless, work on extraction techniques for gas hydrates is taking place at a feverish pace, financed by oil conglomerates and public funds. In the Gulf of Mexico the Hydrate Energy International company is already active. And what will Russia, which today gets 20 per cent of its state revenues from gas sales, do when it can no longer satisfy international demand for gas with its conventional gas deposits? Can if afford to deny itself a hold on the Siberian frost regions or on the gas hydrates along its Pacific coast?

Emissions-free coal power plants?

Measured by the standard of 'statistical availability', meaning the proportion of estimated reserves to actual annual consumption, there is more certainty about how long coal will continue to be available than there is for other types of fossil energy: about 170 years. But since burning coal produces the highest level of emissions and is under enormous pressure from climate policy, 'clean coal' has become the motto for survival in that business, alongside attempts at increasing the efficiency of power plants, though this is only possible to a limited extent.

As a way of making coal 'clean', one fallback measure is CO_2 separation, already practised with natural gas extraction. How this functions in gas production may be shown by the example of the Norwegian firm Statoil: its natural gas, extracted from the North Sea, has a carbon dioxide content of 9 per cent, which needs to be reduced to 2.5 per cent before it can be sold. The surplus is separated and pumped into a layer of salt 800 metres under the seabed. The cost of the facility was 350 million euros. In this way Statoil has been able to save on CO_2 taxes levied by the Norwegian state. So long as gas production continues to exist, the separation procedure makes complete sense and is relatively easy to operate. If carbon dioxide has already been separated, it is better to store it than to pass it on into the atmosphere, still a widespread practice. In the case just depicted, surplus CO_2 is also transmitted on the spot into a depot near the source.

Things get substantially more complicated when the power plant is meant to be carbon dioxide-free. In this case the CO_2 that was separated and cleaned has to be brought via pipelines to a storage site, such as a salt cavern. There must be guarantees that the carbon dioxide can be stored here for thousands of years without leakage. Above all, what needs to be avoided is the possibility that large amounts of CO_2 might escape abruptly.

Other conceivable methods might be to liquefy the CO_2, at first using a large dose of cooling energy and then using tankers on the open sea to pump it into the ocean depths where it can dissolve. This, however, entails the danger of incalculable disturbances to the oceanic ecosystem, which Brad Seibel and Patrick Walsh have warned against in the journal *Science*. The carbon dioxide, they argue, would alter the acid content of the deep sea water, which is bound to have consequences for the organisms living there.[32]

The CO_2-less power plant, in any event, means extending the energy chain of coal utilization by several additional links. The costs are higher by a wide margin than in the aforementioned case of natural gas. In 2003 the German federal government's Council on Sustainability submitted guidelines for a 'modern coal policy' along with recommendations for a R&D effort. According to the Council's estimate, the costs for CO_2 separation and 'sequestering' are '20 to over 60 euros per [metric] ton of CO_2 higher than what it costs for efficiency measures, certification prices, and renewable energy', However, since the technology for CO_2-less power plants will not be available before 2020, the efficiency potentials for carbon dioxide reduction would largely be exhausted by that time, and the certification price for emissions trading would rise correspondingly. At that point, then, sequestering carbon dioxide could work 'economically' and motivate countries to adopt climate protection measures they would not otherwise be prepared to undertake.[33]

At the convention organized by the Council on Sustainability ('Innovative Technologies for Electricity Production – On the Way to CO_2-less Coal and Gas Power Plants'), the Council's chair Volker Hauff explained: 'The world's hunger for energy keeps growing – especially in developing and newly industrializing countries, which frequently have large stocks of the CO_2-intensive energy carrier coal. They are not about to renounce falling back on this resource. And who could blame them?'[34] The proper question, however, is this: why shouldn't we actually dispense with them – since, after all, we are talking about a power plant that might be CO_2-less only after 2020? Should one regard new coal-fired power plants as legitimate simply because a country still has large stocks of coal? Must every resource be exhausted down to the bitter end simply because that was the resource used at first? If there were still some 'economic reason' for this, like lower costs compared to renewable energy, it might make some sense. But even the report issued by the Sustainability Council admitted (indirectly, though clearly enough) that this rationale has disappeared. The point was conceded in the sentence cited above, stating that running a CO_2-less power plant today is more expensive than the cost of renewable energy. If renewable energy, however, is already more cost-effective than a hypothetical CO_2-less power plant, the cost comparison will turn out to be even more favourable in the year 2020. Should one, nevertheless, 'not blame anybody' for picking coal-fired power plants over renewable energy today? Especially since the latter brings with it even more ecological and economic advantages – such as saving enormous amounts of water and restabilizing the water cycle.

The only practical opportunity to avoid CO_2 would come from producing hydrogen from coal, an option pointed out by Amory Lovins.[35] This would be done by taking the hydrogen content of the coal instead of burning the latter; the 'hydro-' would then be separated from the carbon at the mining site and the carbon would either be deposited or used as a solid industrial raw material. Such an approach, however, needs to be measured (see my earlier remarks on hydrogen) against the opportunities presented here that derive from the spectrum of renewable energy fuels. But this approach would at least be more practical than the Sustainability Council's recommendation, which is fixated on coal-fired power plants.

That very Sustainability Council has, in spite of all its other recommendations and professions of loyalty to renewable energy, lent a good word to one of the current energy system's attempts at self-preservation, a survival effort for which there is no longer any plausible justification. It has shirked from the logical implications of its own declarations. A consistent conclusion would have to sound like this: even when the CO_2-less power plant becomes an available option, renewable energy will still be more economical; renewable energy, because it brings along additional ecological benefits, should be recommended as the highest-level priority that is in every country's interest.

Hydrogen economy?

Lately, numerous 'experts' have been raving about using hydrogen as the solution to every energy problem. Most people automatically associate hydrogen with renewable energy because they are thinking about 'solar hydrogen'. Just recently the hydrogen discussion experienced a major boost. Jeremy Rifkin published his book *The Hydrogen Economy* (in German it had the more dramatic title *Die H2-Revolution*).[36] Romano Prodi, President of the EU Commission between 1999 and 2004, told the Conference on the Hydrogen Economy held in Brussels in June 2003: 'Hydrogen is ... the focal point in an energy revolution.' And he added, somewhat less bombastically: 'The rational solution would be to turn resolutely towards renewable energies – provided we can find a way of storing them.' For this, he indicated, hydrogen would be the best candidate.[37] Hydrogen is not a primary energy. It is contained in water, fossil energy and plants. It can be recovered by electrolysis that splits water into its components, hydrogen and oxygen, or by detaching hydrogen from fossil energy forms or from plants. This always requires an expenditure of energy. Whenever renewable energy is involved, the procedure is emissions-free. If nuclear or fossil energy is used, this merely leads to a spatial shift in emissions.

There is, however, no valid reason to name an era after a secondary energy – and one, to boot, that cannot and will not be playing the main role in the foreseeable future. If hydrogen is going to be mined using renewable energy, then (intrinsically) it is the latter that is playing the lead role. Every kind of renewable energy that can be employed (whether as useful heat, as electricity or as fuel) without taking a circuitous and costly detour via hydrogen can also be used directly. There is really no need to store more than a share of all the renewable energy forms activated. Hydrogen is, as we have seen, by no means the only storage possibility; rather, it is one among many, and it is not in every case the economically most attractive or most efficient choice. For this reason alone there can be no justification for the high-sounding concept of 'the Hydrogen Age', since hydrogen can hardly ever amount to much more than a side track on the renewable energy path. The era in which hydrogen bred by renewable energy will be able to play a more or less major role should be named after the energy foundation actually sustaining it; it will be a Solar Age, for the remainder of civilized history.

When a concept becomes a fashion, it is inevitable that those who discovered the topic will reveal their amateurishness. This dilettantism includes proposals that plead for hydrogen made from natural gas or bio-gas, or for using electricity to mine hydrogen from power plants using biomass or located at dams. But it is simply systematic nonsense to take energy that is already (and therefore continuously) available in stored form and transform it again into another form of energy. Storage is not an end in itself. These proposals demonstrate even more clearly how reckless it is when actual problems of supplying hydrogen go unnoticed. Perhaps this happens because it gives people a way to philosophize, in a manner as unencumbered as possible by facts, about grand perspectives, and to avoid taking any real live initiative that might transform the way society uses energy.

In order for hydrogen to be produced from renewable energy (the only process that is not tantamount to ecological self-deception), the first thing needed is electricity. If this has to be transported across great distances – say, from the Sahara or off-shore wind farms – to a hydrogen production site, the energy loss can be calculated as 10 per cent at the least. Once it has arrived at the point of electrolytic hydrogen production, the electric current separates water into hydrogen and oxygen. At this stage of the transformation, by today's standards, energy losses of 35 per cent can be expected. Should hydrogen in pure form then be prepared for general energy supply, it would have to be liquefied or compressed in special pressurized containers. Liquefaction, for which temperatures of –253°C are required, leads to additional energy losses of about 50 per cent of the hydrogen already produced in small facilities, and to 30 per cent when it had been produced in large facilities. Compression, by contrast, means energy losses of only 8 per cent at 200 bars of pressure and 13 per cent at 800 bars. To transport hydrogen to the consumption sites themselves, not only would a separate infrastructure be required, but there are bound to be additional energy losses, either via the energy that is consumed by the transport vehicles or because fluid hydrogen has evaporated in the pipelines or on transport ships, where long distances can result in losses between 20 and 30 per cent. If, after the hydrogen has been shipped, it is poured into filling stations, the result will be additional losses, and then there are even more losses when the hydrogen is turned into electricity in a fuel cell. In the optimal case, about 20–25 per cent of the electricity employed at the outset emerges as electricity again on the other side, and rather less in the case of liquid hydrogen. It is for reasons like these that Ulf Bossel, the organizer of the European Fuel Cell Forum, speaks of a 'hydrogen illusion'. This is also why Dirk Asendorpf, writing in the German weekly *Die Zeit*, concluded that, although 'heads of state and eco-visionaries' might be raving about hydrogen, this approach was tantamount to 'pure energy waste' from the perspective of physics.[38] And Robert Service has written in *Science* that this approach has been blown out of proportion and not been thought through – and he has criticized the US and Japanese governments, along with the EU Commission, for sinking billions of dollars into this endeavour.[39]

One field where applications for hydrogen are possible, therefore, has to do with storing those kinds of renewable energy that are not available in a stored form anyway or that cannot be conveniently stored. Hydrogen presents a special storage opportunity when, if possible, just one conversion step and no new infrastructure are required. In other words, it should be made available using the most direct links possible, both technical and spatial, to renewable energy facilities, that is, hydrogen that is produced within this framework – from surplus solar- or wind-based electricity – and then transformed back again into electric current. There is also an interesting opportunity for extracting it from biomass, by detaching hydrogen from vegetable hydrocarbons; that would be the bio-hydrogen variant.[40]

The other field of application playing a major role in this discussion is fuels. Fuels are only suitable for hydrogen, however, under narrowly defined preconditions. One application would be to synthesize the hydrogen directly at the site of its production into the aforementioned 'sunfuel'. After electrolysis, there would no longer be additional losses and also no additional need for infrastructure. The supply of bio-fuels is expanded that way. Uses in the form of 'pure fuel' also need to be oriented around the guideline of avoiding additional conversion and transport steps, something that is conceivable only for fleets or for a few very specific fields of application. Hydrogen as an aircraft fuel, for example, could be produced from nearby solar or wind power facilities at an airport, then filled into the airfield's tank depots, and finally taken from there and pumped directly into the planes.

Whoever understands hydrogen properly, viewing it in terms of system analysis, can only conclude that plans for hydrogen conceived in super-centralized and sprawling terms are mere pipe dreams. Hydrogen will either be produced and also reused in a decentralized way, something Amory Lovins also recommends[41] – or it will turn into the next super-flop promoted by energy business lobbies who recognize an opportunity for avoiding structural change in energy supply: hydrogen as a way of saving the conventional energy economy with its big business structure. Whoever talks grandiloquently about hydrogen's prospects today without, in the same breath, advocating an immediate expansion of electricity production from solar radiation and wind power can only have one of three motives. The person:

- means well but is either uninformed or thinking with a one-track mind;
- wants to put off changes in the conventional energy system, and to reassure society, feeding it with false hopes for several decades to come; or
- has producing hydrogen with nuclear electricity in mind, though without wanting to admit this openly.

Most of the many conferences recently convened to discuss hydrogen and fuel cells have that last-mentioned motive; they serve, above all, to exploit the public's fascination with (and fundamental sympathy for) hydrogen as a way of bringing nuclear energy back into play. The greater the enthusiasm with which hydrogen can be presented as an option for the future, the longer the delay in expanding solar- and wind-based electricity, and the faster the realization on the part of a very environment-conscious and thoughtful public (or at least this is what the advocates of nuclear energy hope) that there is no way to bypass nuclear hydrogen. This is why many of those currently voting for hydrogen are actually functioning as part of a pro-nuclear campaign. The only government leader from among the industrial countries who openly and unmistakably acts this way is that 'honest soul' (at least in this respect) George W. Bush. His US$1.7 billion hydrogen programme is explicitly in the service of nuclear hydrogen; to produce nuclear hydrogen, funds are supposed to be diverted from the research budget for renewable energy. The hydrogen campaign is managed by the classic nuclear and petroleum lobby, which – as Rudolf Rechsteiner so aptly puts it – 'has kidnaped hydrogen in order to pursue its own goals'.[42]

This applies not only to the US, but also to the EU. The raucous tones with which Romano Prodi advocated renewable energy at the EU conference on the 'hydrogen economy' are just a superficial cover-up for Europe's complicity in the nuclear kidnapping of hydrogen. The conference was presented a paper from the 'High Level Group for Hydrogen and Fuel Cell' appointed by the EU Commission with the highly promising title *A Vision for the Future*. The paper does contain a statement to the effect that renewable energy is the most important source for hydrogen production. Whenever the documents gets more specific, however, it talks about 'zero carbon hydrogen', which includes nuclear hydrogen. By 2020, the prognosis runs, 5 per cent of all new vehicles would be running on hydrogen, in 2030 it would be 25 per cent, and 35 per cent by 2040. The report recommends employing 'advanced nuclear' fuel for hydrogen production at the outset, to be followed by 'new nuclear' after 2040. Between 2020 and 2030 an extensive pipeline infrastructure for hydrogen is supposed to be created. The EU Commission has already provided US$1.2 billion to this end.

How closely the EU concept resembles the Bush administration's plan is also demonstrated by the agreement reached in Washington during June of 2003 within the framework of the International Partnership for the Hydrogen Economy (IPHE), with the participation of the US, UK, German, French and Italian governments as well as of those of Brazil, China, India, Japan and Russia. Nuclear hydrogen is fully integrated into the IPHE's action list; only in Europe they talk somewhat more quietly about this than they do in the US or Japan. If we take a look at the composition of the 'High Level Group' from the EU, we find among the 19 members 14 companies represented, including car and petroleum concerns, technology conglomerates with a positive attitude towards nuclear energy, and one nuclear physicist in the person of Italian Nobel laureate Carlo Rubbia, as well as the French nuclear research centre CEA – but not a single scientist, institute or business from the field of renewable energy. Philippe Busquin, at the time the EU Commissioner for Research and Development, declared in an interview with the nuclear industry journal, *Atomwirtschaft*, that it was time to proceed with the production of hydrogen 'on a longer term' by using high temperature reactors (HTRs), meaning proceeding along a thermo-chemical path instead of by way of electrolysis.[43] The IAEA is participating in this project.

To be sure, not all of those in the 'hydrogen community' that is taking shape in this manner have the intention of achieving a nuclear energy revival through the back door. The High Level Group is clearly demonstrating, however, that this EU organization plans to pursue the production of hydrogen in a centralized way. To achieve this goal the nuclear energy community has offered its services, and it has done so by invoking the familiar, never-changing argument that not enough electricity could be supplied using renewable energy. The nuclear energy community is extremely well versed in directing billions of public funds onto its grist mill and then squandering them. By getting into the game as a potential hydrogen producer, the nuclear industry is hoping to weaken resistance against nuclear energy among an environmentally conscious public. Therefore the industry has become, though this is still unnoticed by many, the driving – and, from the standpoint of any constructive future prospects for hydrogen, counter-productive – force behind numerous hydrogen conferences.

Renaissance of nuclear energy?

'Solar or nuclear' was the title of a debate on Austrian television I conducted several years ago with a well-known professor of atomic physics. The professor was not one of those members of his guild who likes to whitewash the risks of nuclear energy. But he was convinced about its future prospects, and especially about the indispensability of nuclear energy. Fossil energy, he understood, carried risks that made its use prohibitive, and he regarded renewable energy as something that (unfortunately) did not have enough usable potential to satisfy people's energy needs. His remarks on the subject amounted to a lucky bag of grotesque prejudices, all of which were easy to refute with a few empirical facts – like his assertion that the energy expended on producing a solar facility would be higher than its energy output. The professor was highly irritated about his 'scientific' material, which he had evidently trusted. After the broadcast he told me in a voice that was both moved and moving, 'Measured by what you have said, my professional life was misguided.'

During the 1950s, virtually an entire young generation of scientists came to believe in a future that would be permanently freed of all material afflictions if only we succeeded in banishing the threat of the atom bomb and securing instead a role for the 'peaceful use of nuclear energy'. On the heels of the first nuclear reactors, the fast breeder reactor was due to come on line, a reactor producing its own fuel. And this would soon be followed by nuclear fusion and as much electricity as anybody would ever want, almost gratis and virtually residue-free, for people everywhere and for all time – a veritable vision of the sun on Earth. The philosopher Ernst Bloch wrote in his book *The Principle of Hope*: 'A few hundred pounds of uranium and thorium are enough to make the Sahara and the Gobi desert disappear, to transform Siberia and northern Canada, Greenland and the Antarctic into the Riviera.'[44] Bloch gave no thought as to which direction the water might be heading as it melted and left the polar regions. And in 1958 another philosopher, Karl Jaspers, wrote in his book *The Atom Bomb and the Future of Man*: 'If the atom does not bring us annihilation, it will place all of existence on new ground.'[45]

Nuclear energy seduced people into entertaining hypertrophic notions about how all the limitations and troubles afflicting humankind in the eternal struggle for existence could be surmounted for good. In the 'Russell-Einstein Manifesto' issued in 1954, a statement signed by numerous famous scholars and scientists issuing an urgent call for the abolition of nuclear weapons, it said: 'Remember your humanity and forget everything else. If you can do this, then the way is open to a new paradise; if not, it will mean the end of life altogether.'[46] There was now only a choice between nuclear hell or nuclear paradise – perhaps as a way of restoring some mental balance for themselves in light of what nuclear physics had conjured up in 1945 at Hiroshima and Nagasaki. The promise of nuclear energy was regarded as an immense unfolding of productive forces that would bring adequate prosperity to people everywhere and radically shorten the pathway from the realm of necessity into the realm of freedom. It was envisioned as the place in which natural science might fulfil the ethical mission it had assumed ever since science – in the intellectual tradition of Francis Bacon's utopian novel *Nova Atlantis* – made mastery of nature in service to humanity its task.

Living with nuclear power?

Not much is left of those promises, which were as dreamy as they were presumptuous. Because of what actually happened at Chernobyl, the promises turned into nightmares. But what has remained are the national and international structures of the nuclear industry, which are struggling to survive and will not settle for the residual chores of managing atomic energy's phase-out. On the world stage the relevant structure is the International Atomic Energy Agency (founded in 1957), and in the European arena it is the European Atomic Energy Community (EURATOM). Also left over are several large nuclear research institutes, not just in Russia, Japan, France, China, India or the US, but also in Germany (though now under a different name); another residual structure is the budgetary priority accorded nuclear energy in the field of energy research;

and then there is the privilege, unprecedented in world history, that lets major nuclear accidents be insured by the states where they happen because the risks are too high for any private insurance company. Another leftover is the mental habit that makes a future bereft of nuclear power plants strike so many people, especially scientists and technicians, as unreal. Because nobody can turn the clock back on knowledge that is already out there, nuclear energy is a fact that cannot be thought away, so it is said. The world, according to this view, must therefore learn to live with nuclear power plants over the long run.

This is exactly how people have talked, and continue to talk, about nuclear weapons. These too, according to their advocates, are a reality that can no longer be eliminated, which is why we must learn to 'live with the bomb'. This attitude has even been the source of an attempt to consecrate the atom bomb with a higher purpose, as an instrument of permanent peacemaking. Nuclear deterrence was declared a unique means for preventing war, which in the future would deter anyone from ever starting a war again. The central piece of evidence adduced for this thesis is the fact that a cold war conducted for decades between two ideologically contrary world powers never led to a 'hot war' and then ended with the bloodless collapse of the Soviet superpower. Nobody will ever be able to furnish proof to the contrary, that a Third World War might not have broken out even without the nuclear deterrent of mutually assured destruction. No logical conclusions can be drawn from a non-event, in this case that of nuclear non-disarmament. Yet by way of this argument the attempt is made to de-legitimize appeals and initiatives for a worldwide supervised nuclear disarmament. What can be demonstrated (and not just as a counter-factual proposition) is that nuclear deterrence was unable to prevent the outbreak of numerous proxy wars throughout the second half of the 20th century. And what deterrence did give rise to was a historically unprecedented arms race accompanied by a misallocation of resources on a global scale – and to an intense ideological cultivation of enemy images on both sides of the cold war: better dead than red, or better dead than capitalist. And, coming soon to a political theatre in your neighbourhood: better Western than Islamic, or vice versa?

In spite of all the emphasis on how nuclear arms have a peacekeeping effect, an attempt was undertaken to prevent additional countries from acquiring the bomb. The political instrument used to this end was the Nuclear Non-Proliferation Treaty (NPT), which went into effect on 1 July 1970. It was meant to prevent, as permanently as possible, the emergence of additional nuclear countries, in return for which it would pave the way for the 'peaceful use of nuclear energy' worldwide. States with nuclear weapons committed themselves in this treaty to nuclear disarmament – an obligation that has never been concretized since the document was signed. States without nuclear weapons have committed themselves to renouncing nuclear armament, but they simultaneously obtain the right to assistance with civilian uses of nuclear energy. In Article IV of the NPT it says:

> *All the Parties to the Treaty undertake to facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy. Parties to the Treaty in a position to do so shall also cooperate in contributing alone or together with other States or international organizations to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of non-nuclear-weapon States Party to the Treaty, with due consideration for the needs of the developing areas of the world.*

This was meant to draw a clear line of demarcation between military and civilian uses; fencing in of one kind of use, expansion of another. The treaty became the working foundation of the IAEA. This organization was meant to be the worldwide monitor seeing to it that no nuclear material gets diverted to building an atom bomb while also providing governments with unlimited assistance in developing their nuclear power plant programmes.

The permeable line separating peaceful and military uses of nuclear power

The history of the IAEA demonstrates that it is not possible to talk about nuclear energy and remain silent about nuclear weapons. For a clean division between military and civilian use has become, as already mentioned, more difficult than ever. Nobody even tried to seize the chance of a lifetime that the epochal shift of 1990/91 provided for an initiative leading to supervised nuclear disarmament worldwide; at least there was no such initiative emanating from the cold war's victorious side. The argument that complete disarmament was rendered impossible owing to the worldwide dissemination of knowledge about how to build atomic weapons is just an excuse. After all, there is also a treaty ostracizing chemical weapons worldwide, a treaty whose observance is substantially harder to supervise because there are many more possibilities for manufacturing chemical than atomic weapons. As late as 2000, to be sure, at the conference held in New York to revise the NPT, the treaty had its previous time limit extended indefinitely – but only because the Clinton administration agreed to end all nuclear weapons tests. Clinton's willingness to end testing has since been rescinded by his successor Bush Jr, who has even taken official steps to develop new atomic weapons ('mini-nukes'). Because a new ideological world conflict is now brewing in the form of an Islamic–Western *Kulturkampf*, there is simultaneously a growing motivation for Muslim states to acquire nuclear arms.

Today the path to nuclear armament always goes by way of civilian use: with the backing of the NPT, it is possible to camouflage preparations for nuclear armament while getting some assistance acquiring these weapons. In the international arms control debate it used to be said, and quite rightly, that what matters more than anything else is the potential – and not just an assessment of whatever intentions the current government may harbour. That government may be entirely credible and not have the slightest intention of converting its civilian nuclear programme into a military one. But what will be done by the next government if it already has a technological potential for nuclear weapons ready to hand? At that point future atomic powers (in addition to the five permanent members of the UN Security Council, Israel is unofficially in the nuclear club, India, Pakistan and North Korea have joined, Brazil and Iraq nearly made it, and Iran might possibly belong in the foreseeable future) would only need to imitate the fine example others have set for them. In his book *Die Politik der latenten Proliferation* (*The Politics of Latent Proliferation*), Roland Kollert describes how the programme, 'Atoms for Peace', was rather more like a case of deception – or perhaps self-deception. Apart from the US and the Soviet Union, all of today's nuclear powers – including France and the UK – started out on the 'peaceful use' track and only acknowledged their military intentions at the 'last minute' of their transition to full-fledged nuclear armament.[47]

If for no other reason than this, propagandizing a renaissance for nuclear energy is hair-raisingly irresponsible. At a minimum, the prerequisite for a country to use nuclear energy is stability in that state's domestic politics and international relations. In how many of the world's countries can these be guaranteed and permanently maintained? The world situation is anything but stable. The bitter irony of nuclear history might some day turn out to be the story of how the wishful thinking of the 1950s – 'no' to nuclear weapons, but 'yes' to so-called peaceful use of atomic energy – turned into its exact opposite: ever fewer nuclear power plants, and ultimately no longer any at all, but in exchange for this more nuclear-armed countries than there are today.

There can be no doubt that nuclear physics is one of the most demanding scientific disciplines. The further along one is on the nuclear pathway, up to and including nuclear fusion, the greater the general respect accorded the outstanding scientific and technical achievement this requires – especially respect for the attempt to analyse the kind of nuclear fusion that takes place in the sun and then actually try copying it on Earth. It would seem inconceivable for this technological marvel not to have some social utility. This may be the reason why, to this day, nuclear fusion has been sheltered from the withering critique directed against nuclear energy, as if the one has nothing to do with the other. But it most certainly is the reason why, to this day, nuclear physicists and their institutions can afford to keep proclaiming one novel achievement after another in nuclear technology – promises that, only a little later, turn out to be completely irredeemable. These broken promises are, nevertheless, usually attested to have greater realism about the future than is the case with ambitious future-oriented projects using renewable energy that have already proven they can work.

In 1993 the University of Munich sociologist Ulrich Beck described the kind of psychologism whereby the attempt is made, at regular intervals, to launch a renaissance in nuclear energy. This is done, according to Beck, using a 'dramaturgy of risk' in the form of a 'competition to repress thoughts about major risks'. One need 'no longer deny' the nuclear danger – but 'only proclaim that other dangers are even greater'.[48] This is a way to enhance the opportunities for nuclear energy all over again, 'and it might even turn out that the environmental movement, yesterday's opposition, will become tomorrow's involuntary ally'. It is against this psychological background that the campaign for a 'renaissance' of nuclear energy is taking place, in a manner that is starting to impress political institutions and the media once more. The three elements of this campaign are the promise of new reactors with lower accident risks, the global climate catastrophe and the assertion that there is no opportunity for replacing fossil energy unless it involves nuclear energy.

The new pro-nuclear campaign demonstrates how fatal the impact can be on public awareness, as well as on the consciousness of political and economic decision makers, when the aims and opportunities of switching to renewable energy are not articulated aggressively enough. This lack of opposition clears the way for assertions like those made by the authors of a June 2004 article ('Back to nuclear power') that appeared in the German magazine *Stern*:[49]

> *A quick salvation is not going to come from nuclear energy. Its problems from the past will not be solved, nor will its plans for the future be available right away – should they even work as promised. To dispense with nuclear power altogether and for all time, however, also seems presumptuous. What we are left with, then, are plague and cholera: atmospheric warming*

> *and the risks of nuclear technology. What we are looking for is medication against plague and cholera.*

This splashy article from the magazine with Germany's second largest circulation – which had been a platform for the movement against nuclear power plants in the 1970s and 1980s – appeared two weeks after the Renewables 2004 conference. And yet this journal is now 'looking for' a medication against plague and cholera. Apparently this conference did not convince the magazine that renewable energy is the very medication its editors are seeking. At that conference, too, only a half-hearted effort was made to persuade anyone about the renewable cure.

Increasing instead of reducing risks

In the 1950s atomic energy garnered broad support because it was portrayed in glowing colours as a great historical prospect, as a project for all humankind. As late as 1974, the IAEA was promising that 4.45 million megawatts of nuclear power capacity would be installed by the year 2000. That is almost double the total capacity installed for electricity production worldwide today. The 'nuclear community' applied no self-restraint of any kind, neither with respect to the numbers it was forecasting nor with reference to the speed at which it expected nuclear power plants to be introduced. They have constantly had to scale back their prognoses ever since. In 1976 the capacity forecast went down to just 2.3 million megawatts, and by 1978 it had declined to a mere 800,000 megawatts. And then came 26 April 1986, the date of the Chernobyl accident. Today there are actually 439 nuclear power facilities worldwide, operating at a total capacity of around 300,000 megawatts and distributed across 32 countries. For the 'higher class' of atomic reactors (the fast breeders), the Karlsruhe Nuclear Research Center predicted in 1965 that installed capacity would come to 80,000 megawatts in the Federal Republic alone, and 450,000 megawatts were projected for the US in 1974 by the Atomic Energy Commission (renamed as the Nuclear Regulatory Commission that year) – both projections for the year 2000. And all those unfulfilled predictions about the nuclear fusion reactor are also lined up along an endless chain. When the UN sponsored a nuclear conference at Geneva in 1955, the first fusion reactor was announced for 1975. Today, 50 years later, the fusion reactor is heralded for 2060. Although the date for delivering on this promise keeps getting further and further away, the funds keep flowing copiously.[50]

The latest projection from the IAEA, which is the basis for the proclamations of a renaissance in nuclear energy mentioned in the Introduction, is even cautious compared to earlier projections. Specific decisions about individual projects are invoked as evidence, like the decision that a new reactor is going to be built in Finland; that France has announced new plant construction for 2007, with facilities that will run for 60 years and replace all of today's atomic reactors; that there are current plans to built 27 new plants worldwide, 18 of them in Asia; and that the US is extending the officially approved life span for 56 of its 102 reactors from 40 to 60 years.

In a parallel development, the consequences of the Chernobyl catastrophe are being downplayed. In the respected German weekly *Die Zeit*, that paper's science correspondent Gero von Randow wrote that there were only 45 deaths there and 'merely' 2000 registered cases of thyroid cancer.[51] Yet the figures came from interested parties. Independent investigations like those of the Radiation Institute in Munich established that there were 70,000 death victims, including suicides out of desperation, and these studies anticipate additional victims from delayed reporting numbering in the tens of thousands. The strategy of soft-pedalling Chernobyl's damage includes miscalculating the number of victims by setting them against those who have suffered from fossil energy emissions and coal mining.[52]

In order to put the alleged economic advantages of nuclear power in a more favourable light, not a word is said about how its economic foundation was and remains a machinery of political subsidies and privileges of the first order. In addition to tax-exemption for nuclear fuels and release from liability obligations, the companies building nuclear power plants have received preferential credit and, in many cases, investment grants of unknown magnitude. Most of the reasons why Electrité de France, which receives 85 per cent of its electricity production from nuclear power plants, is among the most debt-ridden companies in the world are 'atomic' in nature. From the 1950s to 1973, the OECD countries spent over US$150 billion (in current prices) on R&D in nuclear energy – but practically nothing, by contrast, on renewable energy. Between 1974 (when the International Energy Agency started collecting data) and 1992, it was again US$168 billion – for renewable energy, by contrast, the figure came to just US$22 billion. The EU's opulent promotion of nuclear energy is not even included in this count, and the French figures remain secret to this day. Together with the grants provided by non-OECD countries, especially from the former Eastern bloc, total subsidization worldwide comes to at least US$1 trillion; for renewable energy, by contrast, subsidies amount to US$40 billion at most over the last 30 years, including market introduction programmes. In Germany alone since the 1950s, atomic energy was subsidized with the following amounts: about 20 billion euros for building research reactors; 9 billion euros for failed projects like the fast breeder, the high temperature reactor and a reprocessing facility; 14.5 billion euros for plant closings, restorations, rehabilitating deposit sites and final disposal for materials; and about 20 billion euros in lost tax revenues because of tax exemption anticipated for final nuclear waste disposal. The calculation does not include police security measures and expenditures for university institutes or for basic financing of research centres.

By the mid-1970s nuclear energy had largely been thwarted, more as a result of massive cost over-runs than because of growing resistance. Since then, the boundary lines limiting its expansion have been drawn ever more tightly. Estimates that uranium deposits will only last a maximum of just 60 years are based on consumption from facilities currently running; that is, even if the number of facilities were to be doubled, the time available would inevitably be cut in half. Without an immediate transition to fast breeder reactors, which could stretch the fissionable material by a factor of 60, it stands to reason that not even the growth rate calculated by the IAEA could be achieved. Without switching immediately to breeder reactors, it would be impossible to have any kind of comprehensive expansion in nuclear energy, something already pointed out in 1980 by the Bundestag Survey Commission chaired by SPD parliamentarian Reinhard Ueberhorst. Yet the history of the breeder reactor is a fiasco. Thus far, these reactors' high costs and vulnerability to breakdown have made them unsuitable for commercial operation. Klaus Traube – the manager of the German fast breeder reactor project in the 1970s and, for a quarter of a century, Germany's most prominent nuclear energy critic – has documented the failure of the grand ambitions associated with the fast breeder reactor:[53]

> *Germany's 300-megawatt breeder at Kalkar was started in 1972 and then abandoned in 1991 – after 19 years of construction that devoured seven billion marks (25 times the original estimate). An analogous project planned for the US was never implemented. It is true that some demonstration breeders designed for mid-range performance were put into operation in the mid-1970s in France, the UK and the Soviet Union, but they were shut down in the 1990s. During the start of a parallel Japanese project in 1995 a major accident occurred. That particular breeder plant has been out of commission ever since; it is unclear if it will ever be put to work. The world's only large-sized breeder power plant ever put into operation, the 1200-megawatt Superphenix that France started in 1986, was shut down in 1997; in ten years of operation it produced a volume of electricity that corresponded to 7 per cent of its capacity utilization. All that remains is a 600-megawatt Russian breeder plant. In the mid-1980s construction also commenced in the Urals on two commercial 800-megawatt breeders, which were supposed to go into operation in 2000 but were also actually abandoned. This pitiful end to the race for breeders, a competition staged with such lavish funding, is ultimately attributable to the enormous technical complexity and shortcomings in security technology associated with the breeder concept. These characteristics led both to enormous costs and catastrophic outcomes as a result of persistent breakdowns in the plants. Four decades of development in all the major industrial countries have reduced the breeder concept to absurdity.*

There are six additional reasons arguing against any kind of future viability for nuclear power:

- The water problem – nuclear reactors' enormous water needs for steam and cooling compete with the demand for water from a growing world population.
- Minimal efficiency – the waste heat produced by nuclear power plants hardly lends itself to combined heat and power cogeneration. The reason is that long-distance heating transmission from centralized power plant blocks is very expensive. That is why nuclear energy is the energy form with the most meagre opportunities for increasing efficiency.
- Risk vulnerability – in tandem with the growing risk of 'new wars' (wars no longer carried out between states) there is a parallel rise in the worldwide danger of nuclear terrorism – and not just from aircraft attacks on reactors.
- The wrong energy business plan – since investment in nuclear power plants is especially capital-intensive, building these plants clashes with the liberalization of electricity markets and their short-term amortization periods.
- The time perspective for final disposal – nuclear waste needs 100,000 years to be securely stored. In light of growing risks of social instability, what political system can provide guarantees for such a lengthy term?
- Creeping radioactive contamination – nobody can estimate the long-term risks that releasing radioactivity harbours for nature and for human beings, even on a small scale. The more nuclear power plants there are in operation, the greater the danger.

Nuclear fusion as the last straw

Thus, the only prospect that remains is the nuclear fusion reactor, of which nobody today can say for sure if it will ever work. The operating principle of this reactor is that two hydrogen atoms (deuterium and tritium) are fused in a hot gas. The gas has to be heated for a few seconds to 100 millions degrees Celsius – 'hotter than the heat of the sun', as nuclear fusion researcher Eckhard Rebhan titled a book on the subject.[54] To achieve ignition, an even higher temperature of 400 million degrees Celsius is required. Even if there were no other environmental risks and we based everything just on the costs estimated by nuclear fusion researchers (and let it be recalled, all cost projections made by nuclear researchers have consistently proven to be vastly understated in practice), there is no rational economic reason to develop and introduce these kinds of reactors.

Japanese fusion research, for example, puts construction costs at US$2400–4800 per kilowatt, which comes out to a price of between 14 and 38 cents per kilowatt hour.[55] The lower figure is already higher than average costs for wind-based electricity in Germany today; the upper figure is higher than what it costs today for PV cells in southern Europe. Alexander Bradshaw, Director of the Max Planck Institute for Plasma Physics and scientific director of Germany's nuclear fusion research, put the cost at between 6 and 12 euro-cents when he testified at a hearing of the German Bundestag.[56] But he, like the aforementioned Japanese study, did not mention that the walls for the reactor have to be replaced every five to eight years, and that the replacement itself can take one to two years. These would be radiated components that would have to be stored as nuclear waste. Because of the lengthy periods when the reactor would be out of commission, there would have to be at least one substitute reactor as a standby for every two or three reactors actually running, which quickly pushes costs up even higher.

One study not conducted by a fusion researcher was drawn up by Emanuele Negro for the EU Commission. This study arrives at costs for producing electricity that are seven times higher than the expense of a nuclear fission reactor, calculated over a term of 30 years. Negro compares these costs with the degressive costs calculated for PV energy through the year 2050 – in other words, before nuclear fusion would even be available theoretically. He arrives at the conclusion that PV costs can draw even with those for producing fossil electricity today, while to 'the best of our knowledge' nuclear fusion costs would be five times higher.[57] This confirms what the former deputy director of the Plasma Fusion Center at the Massachusetts Institute of Technology, M. L. Lidsky, had already said more than two decades ago: nobody will want this reactor the way it is meant to be built.[58]

It is a myth, moreover, that nuclear fusion reactors pose no environmental risks. While they are operating, the material inside the core reactor becomes highly radioactive, which entails very costly waste disposal. Although this material, in contrast to the nuclear fuel rods used in atomic fission reactors, is only active for about 100 years, the amounts are considerably larger. The tritium required for fusion is capable of penetrating solid structures, and it turns into tritiated water after contact with air, which can cause the most serious kind of biological damage once it gets into the water cycle. Nuclear fusion reactors have an enormous thirst for cooling water. If for no other reason than its need for cooling water, this reactor technology has an inherent disposition towards being employed in highly concentrated production centres. There is talk of building reactors on a scale ranging from 5000 megawatts to as much as 200,000 megawatts.

Between 1974 and 1998, total costs for nuclear fusion among the OECD countries were already around US$28.3 billion. The test reactor called ITER, planned for use in an international cooperative effort and meant to be finished by the mid-2020s, is estimated to have construction costs of US$3.5 billion. A follow-up demonstration reactor is meant to be built for US$8 billion. No matter how highly skilled nuclear fusion researchers have to be in their training and work, the statements they make when asked about renewable energy are inept. Renewable energy's technological shortcomings are subjected to denunciation as permanently insurmountable drawbacks, even though renewable energy already has a proven track record of productive performance. The fusion experts seem to think it is more realistic to develop materials that can withstand temperatures of over 100 million degrees Celsius than to contribute towards introducing renewable energy on a broad scale.

For nuclear fusion researchers, the breathtaking technological performance they expect from a fusion reactor (should it ever succeed) is matched only by the downright subterranean level at which they rate renewable energy. In the Bundestag hearing mentioned earlier, the physical chemist Professor Alexander Bradshaw had this to say in response to the question of whether nuclear fusion was even necessary in light of the prospects for renewable energy: 'The sermons preached by the mendicant orders of the High Middle Ages, seeking happiness in a simple and impoverished life, were only followed by a few people even at that time.'[59] The protagonists pushing today's nuclear energy renaissance are certainly not at a loss for cognitive ability, but they do lack the will to acquire knowledge about renewable energy. If they were ready and willing to learn about what renewable energy has to offer, they would have to come out on behalf of stopping the nuclear fusion programme and in favour of concentrating on optimizing technologies for renewable energy. But since they are not about to head down this path on their own, the only remaining option is to stop fusion research by political means.

The last rearguard action of the established energy system?

Today the world confronts an existential decision about how energy will be supplied in the post-fossil era: it faces a choice between 'solar' and 'nuclear'. In reality, the future prospects for nuclear energy – which the writer Carl Amery has called the 'lazy magic of the Sorcerer's Apprentice' – are anything but positive, even if there were no resistance to the nuclear option. That is why the projections associated with nuclear energy play such a big role. Projections serve as a kind of bail bond for the traditional energy system, which is on trial in the court of a public opinion that recognizes the need to reorient society around renewable energy, especially against the background of the global climate problem. The preference of big business for atomic energy arises from its belief that teaming up with nuclear power facilitates its domination of the energy sector. If we lived in a looking glass world where nuclear energy could only be used in a decentralized form and renewable energy only by way of large power plants, it is a safe bet that the suppliers of fossil energy would have rejected the former and always opted for the latter.

The motive for the propagandists of nuclear energy's renaissance may be tactical or just pure presumption. It would be tactical if they were merely working towards maintaining the status quo at current levels, knowing all the while that the clock is ticking for nuclear energy. Just to succeed at this modest goal, the 'nuclear community' needs to exaggerate its own importance in a systematic way and denigrate every alternative. But maybe it is also presumptuous enough to hope that the fast breeder reactor might be made to work so that modern societies, using current nuclear technology and the last ton of uranium, can still reach the saving shore of nuclear fusion. In the meantime (according to this scenario), fossil energy will continue to be the primary way of bridging the era between fission and fusion. These kinds of hopes were described satirically by Carl Amery in a conversation he had with me and *Die Zeit* editor Christiane Grefe that was later published as a book under the title *Klimawechsel* (*Climate Change*): They resemble the hopes of a penniless man who orders one course of oysters after another in a restaurant so he might eventually find the pearl with which he can pay for his gluttony.[60] Money is no object so long as the systemic shift to renewable energy can be prevented. 'Anything but renewable energy' is the secret motto.

Yet the atomic and fossil energy system can no longer be expected to win the last battle in its war for self-preservation. The attempt to prevent a practical reorientation towards renewable energy by loading the dice on future options is bound to fail. There is no way that the technological opportunities for using renewable energy can be permanently silenced and undervalued. The most one can do is keep holding them back – in much the same way that has already been happening long enough. This thought is hardly reassuring, for the danger is too great that the established energy system's impending decline will drag society down into the abyss along with it.

The world view that rested on the hope that all of society's problems could be solved by science and technology led to a reification of the latter and to a discrepancy that the philosopher-writer Günther Anders had already described during the 1950s – before we had any real experience with nuclear technology – in his book about 'human antiquatedness'.[61] The discrepancy Anders described was one between technological perfectionism and the persistence of human fallibility. How lasting our infallibility has proven to be is something the ethnosociologist Hans Peter Duerr has forcefully shown in his five-volume work, *Der Mythos vom Zivilisationsprozess* (*Myth of the Civilization Process*).[62] There are no safeguards on any aspect of civilized progress, and the danger of reversion to anarchy is omnipresent. Nothing demonstrates this more clearly than what at first glance seems to be the paradoxical core contradiction of our time: the modern world's flood of scientific knowledge has not been able to prevent human-made natural destruction from becoming steadily greater on a global scale. Günther Anders speaks of a 'Promethean shame' that afflicts humans in the form of a growing sense of insufficiency vis-à-vis the fruits of technology. Humans trust technology more than themselves and have developed a limitless faith in technological feasibility. Man has 'deserted into the camp of his appliances' and subjugated himself to their power.[63] This is no longer a matter of consciously choosing the appropriate technology, which would include a conscious renunciation of outdated technologies; instead, this is all about simply perpetuating technologies by mindlessly continuing to develop them.

Every linear development eventually reaches a breaking point when the cycles of nature, society and economics start to stand in its way, when the development no longer has sufficient feedback and its own control variables stop changing in response. If a system is overpowering, it can extend its existence unduly for a while. Yet, as they grow larger, the corporations that supply energy also become more immobile – not in spite of their capital and organizational power, but because of them. At this point their attempt at self-preservation persists even against the better judgement of those who are in charge of the system, to whom all the possible breaking points cannot have remained a secret. Today's energy system is capable of ignoring the limits set by global climate change longer than anyone. The Kyoto Protocol, a subject we shall soon address, is not preventing the system from acting evasively. The consequences of climate change do not immediately affect its perpetrators. But there certainly is an impact from other energy-determined crises. That is why there is growing reluctance on the part of capital markets to provide billions in credits for large power plants and the extensive infrastructure they would require. This anxiety was also on the mind of those attending that family reunion of the global energy business, the World Energy Conference. It issued a call to improve public acceptance of the energy system – through public relations.

The first sentence of the final communique from the 2004 World Energy Conference reads: 'All energy options must be kept open and no technology should be idolised or demonised.' What this meant was that renewable energy should not be idolized and nuclear and fossil energy not demonized. In other words, nuclear and fossil energy should be presented to the public consciousness as equivalent to renewable energy. This 'equivalence' can only be contrived, however, by trivializing the problems and dangers of nuclear and fossil energy and by systematically playing down the technological and economic opportunities associated with renewable energy as well as its manifold social advantages. A broad-based campaign is meant to persuade people that the system of nuclear and fossil energy supply is innocent of any role in energy-related crises and to dissuade governments and societies from turning to renewable energy. On the basis of that assertion about equivalence with renewable energy, the only thing then meant to be decisive is the market price for energy. In order to facilitate formulating this price to the detriment of renewable energy, control over the structures of energy supplies needs to be secured. In order to prevent alternative ideas from even occurring to anyone, the supposed technological and economic advantages of traditional energy compared to those of renewable energy – in spite of the former's untenability and lack of technological imagination – are meant to be chiselled in stone. These are the exculpatory lies that serve to conserve the established energy system, lies the system uses in its attempt to justify its continued existence. All this is a bad omen for 'rationality' in dealing with renewable energy. Lately, strategies of sowing confusion are being used not only to dispute the potential of renewable energy for replacing nuclear and fossil energy, but also to contest renewable energy's environmental edge.

The question is not just how long capital markets and insurance companies will continue to fall for this strategy of confusion when they prepare their risk analyses. It is also a question of how many governments and parliaments will continue to want to support the established energy system's self-preservation strategy – and, if they do, whether they then have the financial clout to raid the state's coffers again for the sake of a nuclear energy renaissance. It is also questionable as to how long the public will let itself be deceived – and as to how many of the forces inside the energy system will hold out in maintaining this self-deception and submitting to the esprit de corps of the energy fraternity's old boys network.

There is no other choice except to break the structural power of the established energy system, to block the artery keeping them on artificial life support, and (quite independently of that) to mobilize the forces for renewable energy. Yet what methods of political, economic and social action should be used, and who should the players be in this endeavour? In Part II we shall show that change will not be possible based on the fundamental assumptions that shaped previous activism. These assumptions tend to cripple the players who are available and hinder the activation of many additional players who will be needed for the shift to renewable energy.

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