Vulnerability of Modern Energy Systems: Implications for Democracy, Security, and System Transformation

L'article ofereix una introducció de les característiques generals dels sistemes moderns d'energia i dels reptes que se'n deriven, seguida d'una anàlisi de la possible evolució que tindrà la disponibilitat del combustible fòssil. A continuació se centrarà en les condicions i les possibilitats de la transformació del sistema energètic a llarg termini.

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El artículo ofrece una introducción de las características generales de los sistemas modernos de energía i de los retos que se derivan de ellos, seguida de un análisis de la posible evolución que tendrá la disponibilidad del combustible fósil. A continuación se centrará en las condiciones y las posibilidades de la transformación del sistema energético a largo plazo.

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The article gives an introduction to general characteristics of modern energy systems and resulting challenges, followed by an analysis of the possible development of fossil fuel availability. The subsequent part will discuss requirements and options for far-reaching energy system transformation.

Vulnerability of Modern Energy Systems: Implications for Democracy, Security, and System Transformation

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In recent years, questions regarding energy supply have risen on the public agenda, driven by events like Katrina and the resulting shortfalls in fossil fuel production and refining. These questions have also grown in importance because of a sharp increase in energy demand from countries like China, India, but also rapidly growing industrialized countries like the USA. Natural disasters and serious electricity blackouts in a number of countries show how dependent our societies—in industrialized as well as developing countries—are on the constant supply of energy. Ongoing terrorist attacks on facilities of the fossil fuel industry also show how fragile our energy infrastructures are, on all levels, from the global to the local.

Characteristics of Modern Energy Systems

The vulnerability of modern energy systems is a function of their complex characteristics. First, heavy use of carbon-rich fossil fuels is one defining feature of today's global energy complex. Oil, coal and natural gas dominate. Low-carbon nuclear fuels and renewable energies play a secondary role. Different energy carriers have different specific infrastructural requirements and implications on system vulnerability. In some cases, supply is secure, in some cases not. In some cases, substitutes are readily available, in others not. The primary energy carrier coal is mainly converted to the secondary energy carriers electricity and heat. The same holds true to a lesser degree for natural gas. Oil is dominating in the transportation sector; in heating it is in some countries also important. Renewable energy sources are used for electricity, transportation and heating.

Second, for decades, the energy industry, especially in electricity generation, has used economies of scale, building infrastructures comprised of large generation units and large-scale transmission lines and distribution networks. Centralization was the result.

Third, modern energy systems and modern economies need a constant energy supply—no interruptions, "24/7"—hence the need for constant *security* of supply. There is nothing more "dangerous" to modern economies than experiencing an unforeseen disruption. Unlike oil, which can easily be stored in tanks, storing electricity is extremely difficult. Technologies for efficient large-scale storage are not on the markets.

Fourth, extrapolating historical trends, world energy demand will steadily increase in the future. (In this context it has to be mentioned that ever increasing energy consumption is not at all a prerequisite of economic development, least of all an iron law, because of available energy efficiency potentials even in industrialized countries.) In sum, today's global energy system is characterised by:

- Heavy use of fossil fuels;
- Centralized and large scale structures throughout the supply chains;
- Reliable 24/7 supply;
- Rapidly growing demand.

Specifically fossil energy also shows a number of specific characteristics. The number of relevant oil and gas suppliers is decreasing, whereas the number of relevant consumers—mostly from the large group of developing countries—is increasing (EU 2004, IEA 2004). The remaining suppliers are growing more dominant, gaining more market power and more political power. Import dependence is growing, and will grow much more in coming decades. Remaining reserves are more expensive to extract. Finally, supply lines cover ever greater distances.

Disruption of Supply and Causes of Vulnerability

The requirement of *constant* supply is *the* major cause of vulnerability. In other words, disruption of supply is the major threat to fossil-fuel-dependent economies. It is the "background noise" that sets the context. Here, there is a difference between the concrete disruption of supply (notably terrorism, strikes and political risks) and general causes of vulnerability (import dependence, rapidly rising demand and centralization). The former involves direct interventions in the functioning of the energy systems, the latter address the overall structural conditions of these systems.

Addressing causes of disruption of supply the first to mention in the current global context is terrorism. Iraq shows that infrastructures of oil and gas production make easy targets for terrorist attack. Since the end of the Baathist regime in Baghdad, more than 200 attacks on oil production sites, on pipelines, on hubs, and on port facilities have occurred. This has lead to a significant reduction of oil exports, resulting in an estimated financial loss of about $11 billion for Iraq between June 2003 and May 2005. Environmental damage due to oil spills alongside pipelines also has costly consequences. Saudi-Arabia spends $1.2—1.5 billion annually for security measures for oil and gas production, transportation and refining facilities (Gasandoil 2005).

In October 2002, terrorists targeted a French tanker off the coast of Yemen. If attacks like this one succeed, environmental damage due to the oil spill will probably be significant. The situation could worsen by an attack at a strategically relevant so called choke point of tanker transport like the Strait of Hormuz, the Suez Canal or large terminals. Sinking a tanker would then create a major disruption (EIA 2004). This is an extreme scenario, but not an unthinkable one. The number of tanker transports is large (and growing) and security measures have logistical limits. Thousands of oil and gas production wells are decentralized, but the logistics of oil and gas depends on a few central "hubs". These are loading ports, highly frequented shipping routes, refineries, pipelines (often with capacities of a million barrels per day or more, in the case of natural gas, billions of cubic meters capacity per year) and hubs with storage tanks in areas of high consumption.

The problem of centralized structures is even more apparent in electricity generation: large generation units and transmission lines (high-voltage grid) dominate, offering easy targets for terrorist attacks. That there have not been many such incidents is probably due to the limited effect: modern electricity grids allow failures and malfunctions of power plants to be compensated for by other plants. But with nuclear power plants, the issue is not the disruption of electricity supply but the damage caused by radiation.

The widespread blackouts in the USA, Italy, France and other countries in the years 2001 to 2004 revealed another type of vulnerability. In partially liberalized markets, structures with a large degree of centralization are by no means failsafe. Indeed, resilience decreases under these conditions. Large-scaled centralization meant that blackouts were also large-scale. Labor unrest is another cause of disruption to fossil energy supply, giving evidence of how dependent oil supply and oil prices are to small scale disruptions. In 2004 and 2005, strikes in Norway, Nigeria and Venezuela led to price jumps on the global market, although production losses were negligible. The reasons: nervousness among the market players and general insecurity ("what would happen if more strikes reduced global supply?").

Talking about disruption of supply, different patterns have to be discerned. The general pattern among terrorist attacks and strikes is that disruptions are often small or negligible on a global scale (with certain exceptions), that they are not centrally coordinated by an organizational body, and that they don't follow an international strategy.

Political Risk: Arising from Unexpected Sources?

The opposite is the case with political risks. The term is often applied to describe the situation in the Middle East. The region is usually seen as politically unstable, constantly threatened by subversion and religious fundamentalism. Some experts do, however, disagree, believing that countries in the Middle East are more or less politically stable: they may not be democratically legitimized, but the ruling elites would not be directly threatened by upheaval and revolution (Fürtig 2006).

The power of OPEC should not be overestimated. Of course the world is becoming more dependent on OPEC oil (and gas), and its political power will therefore increase, and OPEC countries generally seek to maximize profits—which is a common principle of capitalism. But OPEC is an aggregate of quite different (developing) countries, each dealing with special challenges like environmental stress and accompanied health risks for their populations, poverty, unemployment, and more. Like the consuming countries depending on oil supply, OPEC countries depend on revenues from oil exports. Extremely high oil prices bear major risks for OPEC countries themselves, among these are promotion of alternatives to fossil fuels and reducing dependence on OPEC. These alternatives have the potential to reduce OPEC power. OPEC´s oil price corridor (keeping prices between US$ 22—28) was an instrument to maintain profit maximization and market share without creating the impression that the eleven countries would blackmail the world with the oil weapon. This instrument will probably not be used by OPEC anymore, and this scenario does not seem very realistic. Indeed, OPEC is very much interested in stable market environments, not only trying to maintain security of supply, but also claiming "security of demand" from consumer countries (OPEC 2006).

Another setting is a scenario of political overthrow, comparable to the Taliban regime in Afghanistan. If such a regime came into power in Saudi Arabia, which provides about 15 percent of global oil, the oil weapon could of course be used, and it would probably be in the logic of Islamic fundamentalism to use it to harm the economies of the Western societies. However, this is speculation, and more realistic situations are at hand.

The Ukraine gas conflict shows another facet of political risk, and here it becomes obvious that political risk is the link between the disruption of supply and causes of vulnerability. This conflict was symptomatic—a clear example of the kind of challenges the future will bring.

The conflict developed as follows. All eastern European countries are somewhat dependent on Russian natural gas. The same holds true for Western Europe. Russia wanted Ukraine to pay a "world market rate" for Russian natural gas (Stern 2006). This position is reasonable, as Ukraine received gas from Russia at a "friendship rate" in the past. Other countries like Belarus still get gas with these conditions. So why does Ukraine now have to pay twice as much than before? Import dependence bears—apart from forgone domestic value creation—the risk that independence of decision making on international level is reduced. Import dependence, as a challenge for national energy systems and cause of vulnerability, is a growing global problem. The consumers on the one side increase in number (as developing countries enter the global market and compete for oil and gas) and the consumers increase absolute demand. On the other side production capacities continue to decrease in the major consumer regions; the remaining producers thereby increase their power. Growing demand for oil and shrinking domestic capabilities to meet that demand leads to enhanced international competition for the remaining oil reserves. For probable increase of oil import dependence see **Figure 1**. The global natural gas system shows a similar pattern of dependence: three regional markets (North America, Asia, Europe) make dependence on the regional suppliers even more pronounced, global gas trade can only be accomplished by liquefied natural gas (LNG), which indeed is becoming more and more attractive for a variety of players. New players like China will shape the emerging global gas market. China might import 30 percent of its gas in 2030—up from zero percent in 2000 (IEA 2004).

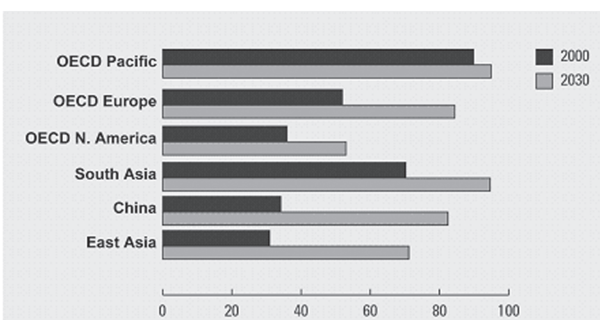

Figure 1. Oil import demand of different world regions in percent of total oil demand. (IEA 2002)

Energy import dependence bears various problems for democratically legitimized nations. (Solely foreign policy aspects will be discussed in the following.) In the case of Germany, dependence on Russia is increasing, as imports from Norway, Great Britain and the Netherlands are decreasing (due to declining production). In the European Union imports from the Middle East and Russia will increase. The decision has to be made whether or not dependence on countries which are lacking democratic legitimization should be increased, dependence on countries having significantly different ideas of freedom of opinion, of human rights and other values regarded as *conditio sine qua non* for democratic societies. This decision is essential for two reasons:

1) Having to tolerate such structures in energy rich countries leads to the establishment of double standards, as exactly the same structures are condemned in other countries. The question of credibility directly arises in this context.

2) Relations with the energy supplying countries can change: political leverage is narrowed for the importer, "inconvenient views" will probably not be expressed in the same way as before (Supersberger 2006). On the other hand, political leverage for the exporter is expanded.

Adding Peak Considerations and Substitution of Energy Sources

Increasing prices have dominated the global energy markets, partly due to short-term supply shortages, partly due to strong growth of demand, partly due to tight production characteristics (little spare capacity for oil production). Most of the relevant non-OPEC oil producers reached production maximum and have entered the stage of production decline, while the competition for remaining reserves gets more aggressive (Skrebowski 2004). Expectations are on OPEC to match increasing demand by increasing production. Yet the cartel finds itself in a dilemma: it is expected to increase production, hence market share, but increasing market share is judged by many non-OPEC countries as a threat to global economy, putting the fate of global economy into the hands of such a few countries.

Fossil fuels are finite, non-renewable resources. The statement that oil will last for "another 40 years" at current consumption rate is misleading. Consumption is increasing (so that current consumption as reference is worthless) and, more importantly, it is impossible to produce from an oil field at constant rate until the last recoverable unit is extracted. A realistic production profile generally follows a bell shaped curve with a production maximum when about fifty percent of the recoverable oil is produced (the so called depletion mid point), possibly followed by a short plateau (see **Figure 2)**. After this *peak production rate,* productivity decreases; the field is then "in decline." This is valid for single oil fields as well as their cumulated number on global scale (Aspo 2005, Laherrere 2004). The discussion focusing on a static range of fossil fuels is distracting attention from the basic problem: the world will experience supply restrictions long before the world "runs out of oil". The crucial point is when demand further increases but supply cannot follow. The resulting gap will lead to soaring oil prices.

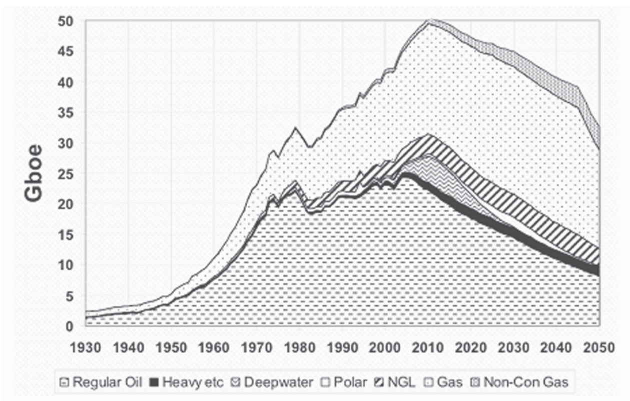

Figure 2. Production peak for all fossil hydrocarbons (oil and natural gas), as projected by Aspo (2006).

Substitutes to conventional oil offer numerous opportunities. One branch of substitutes is utilizing other sources of fossil fuels, such as tar sands, heavy and extra heavy oil production, and synthetic fuels from coal and natural gas. The second branch of options is comprised of renewable energy sources like wind, solar energy, biomass, hydrodynamic energy (waves, tides, rivers and storage lakes) and geothermal energy; and last but not least, enhanced energy efficiency and energy saving.

Substitution of fossil fuels by other fossil fuels bears numerous counterproductive effects: the production processes of all the substitutes need more energy and usually consume more materials, e.g., water, and emit more greenhouse gases. One of the unsolved problems of using tar sands is their severe environmental impact on two sides: local damages due to open-pit mining and significant energy demand for processing and upgrading to synthetic oil, hence increased greenhouse gas emissions (plus emissions of other pollutants). At present, Canadian discussion revolves around whether to use gas to fuel tar sands production (as hitherto) or to sell gas to the United States directly. Substitution of conventional oil by natural gas through gas-to-liquid processes (GTL) is an energy-consuming process with currently low efficiency. The long-term strategic issue of GTL technologies will be that demand for natural gas would increase even faster than it already does, and structural supply restrictions of gas would occur sooner than currently expected. The only answer would be tapping remote gas resources that can not be used for anything else (Agee 2004, Syntroleum 2004)[1]. For coal-to-liquid CTL (Yamashita/Barreto 2003), the situation is different: In addition to the energy intensity of the process chain and subsequent increased carbon dioxide emissions (if carbon dioxide capture and storage proves impracticable), the challenge would be to find a socially acceptable way of increasing coal production, as in many countries appropriate standards are lacking. E. g. in China, which will soon build a large-scale CTL-plant, about 8000 persons die in coal mines per year due to insufficient security standards (FAZ 2004).

There is discussion as to when this production peak for conventional oil, as well as for all hydrocarbons, will occur. Some experts hold the view of an early peak for conventional oil in 2010 or even sooner, other experts speak of a time frame between 2015 and 2020 or later. A minority deny the possibility of a production peak at all. This debate often digresses into specific details—and the context gets lost. This context is the low flexibility of current energy systems.

Inflexibility is the major weakness of current energy systems. They are too inert to be able to respond to abrupt changes. Adequate reactions on structural supply restrictions take decades. To recall: the transport systems are almost totally dependent on oil products; electricity generation depends increasingly on natural gas (with a major share still from coal); heat production for industry, commercial and residential sectors use oil and gas. Inertia derives from different sources, among them consumer behavior, but also powerful lobby groups trying to prevent system change. On the structural side, inertia results from the long life-time of power plants (up to 50 years), pipelines and other infrastructures. Indeed, inertia is used as an argument for keeping current structures, not initiating structural transformation.

Finding substitutes for fossil fuels has never been regarded as an inert process. Replacing conventional oil by non-conventional fuels (see above) has always been judged as a smooth process mainly driven by economic factors. The

[1] For further discussion on cost regimes and other aspects of gas-to-liquid processes see Lounnas/Brennand 2002, RGS 2003, ZDS 2003

rationale was that rising oil prices would make fossil alternatives, one after the other, economically feasible. After reaching cost effectiveness, they would contribute to the overall energy supply. The error in reasoning is that economical criteria are not the only influencing factors; the described automaticity only works in more or less narrow confines. Leaving factors like social acceptance and environmental sustainability aside, two other essential determinants were ignored: possible long-term contribution on global or at least national scale, and velocity of dissemination of alternatives. Even companies investing in tar sands believe that tar sands products will only play a marginal role for global supply, and this is due to non-economic reasons (Cox 2004). The velocity of market introduction of alternatives depends on the time required to build up significant production capacities, on necessary new infrastructures, long planning periods for large scale facilities (e.g. power plants), complex research and development tasks, and restrictions of non-energetic resources essential to certain technologies.

The previous analysis focused on the *vulnerability* of energy systems. In sum:

1) Current energy systems are intrinsically vulnerable. The structure of the systems themselves causes this vulnerability; thus only the alteration of these structures can mitigate the problem.
2) The current systems are dead ends as they are rooted in the depletion of exhaustible resources.
3) Rapidly growing import dependence is part of the problem.
4) The large degree of centralization (e. g., in electricity generation) is another.
5) Global energy demand increases, and new players, especially among the developing countries, start to claim a larger share of the global energy supply.
6) Competition for energy resources might lead to violent conflicts.

Transformation of the Energy System as Prerequisite for Future Risk Minimization

The energy infrastructures today are because of the mentioned reasons in critical condition. Built without considering resource limitations and complex relationships between diverse players, they are now less able to meet the needs of modern societies. For the long-run, security of supply without harming social and environmental contexts can no longer be guaranteed. The current non-sustainable trends of these energy systems need far-reaching transformation.

There are two pathways to deal with the challenge of rising energy insecurity, increasing vulnerabilities and secondary effects of fossil energy use (e. g. climate-change refugees) (Hennicke/Müller 2005)). The first is coping with the effects and choosing ever more drastic measures to keep control. As a last resort, military force would be used, be it for securing supply lines, be it as an instrument of political pressure, or be it for gaining access to fossil fuel by force. The risks will not vanish with military involvement. They could only be reduced to a limited degree. The question arises how fossil-based centralized energy structures can fit into a setting of increasing global security risks.

The second pathway and a possible way out of the dynamics of ever increasing risks is a far-reaching transformation of supply and demand structures. This should be the major task of the coming decades, aiming for security of energy supply and overall energy security. However, depending on the different players and their mindsets, the answers to these exigent challenges are often nothing more than small pieces of a strategy without broader context, with many players driven by all possible motivations but long-sighted security. This is valid for Germany as well as the European Union: Even if there are success stories, a concise and coherent long-term energy strategy is missing. A first framework for such a strategy should include the following elements:

1) Reduction of relative (and absolute) import dependence to an "acceptable" level through development of domestic energy sources. The aim would be to regain control over national energy supply and to minimize susceptibility to political pressure from supplier countries;
2) Decentralization of the energy system, especially the generation of electricity;
3) Reduction of absolute energy demand by introduction of strong energy efficiency measures;
4) Development of a new understanding of international cooperation in the field of energy supply.

Whatever the nature of the specific substitutes, the process of far-reaching transformation will take 20 to 30 years. Assuming a rather early oil production peak, say in 2015, natural gas following about twenty years later, would mean that this. peak with subsequent decline will aggravate the described situation: Competition for cheap oil will give way to competition for oil *at all*. Economies, hence countries, will become much more vulnerable to (political) pressure from producer countries. The need for oil could lead nations to deploy military forces to open access to oil sources. Nations not using such extreme measures will be left empty-handed. Wars for resources have happened (albeit for other reasons than securing supply, e.g., the Biafra-war in the 1960s and in parts the first Gulf War between Iraq and Iran 1980-88), and they could happen again, this time for securing supply. The inertia of our energy systems excludes quick reactions. So the later adequate strategies to react in this inert system are created, the more pressing the consequences of these structural production declines will be.

Options for System Transformation

Decentralization, reduction of vulnerability to external and intrinsic risks, reduction of import dependence and environmental protection are the four sides of the energy tetrahedron.

In the following emphasis will be put on Germany. Germany is characterized by high energy demand and high energy-import dependence, and is in these respects comparable to many other industrialised countries. Reduction of import dependence needs to stress use of domestic energy sources. In Germany, different types of coal and renewable energies can be used, whereas oil is not available in significant amounts, domestic natural gas playing a minor role as well. Coal provides about 25 percent of total energy demand, oil products and natural gas, 36 and 22 percent, nuclear and renewable energies, 13 and 4 percent, respectively. More than 95 percent of consumed oil is imported, more than 80 percent of natural gas (mainly from Russia), 100 percent of nuclear fuels. Only hard coal and lignite are produced domestically (but more than half of hard coal demand is provided by imports). Renewable energies are also domestically produced.

Although energy intensity (energy used per unit GDP) in Germany is low compared to world average, many options for further reduction of energy consumption remain: be it in household appliances, insulation of buildings, efficient vehicles; be it in energy saving by changing individual behavior, material efficiency and much more (WEC 2004). Therefore energy efficiency can contribute significantly to the reduction of total energy consumption and reduction of absolute import dependence: not using energy means not having to import it. Benefits like domestic value creation and technology development (creation of export markets) are also important. Widely achieved energy efficiency gains will facilitate the transformation of the centralized energy systems to systems with large shares of decentralized generation, because less energy demand will naturally reduce the demand for power generating units, hence making system transformation cheaper than often assumed. The benefits of small systems are obvious: blackouts will of course still happen, but they will not have severe effects on the economy because they will be limited in dimension. Resilience will increase. A decentralized system will not offer attractive targets for terrorist attacks, like large nuclear power plants do. Small systems are in most cases more efficient (e.g., because no long-distance power lines are necessary). They are cheaper and faster to build. Furthermore, decentralization is a prerequisite for the introduction of renewable energies—and vice versa.

Regrettably, the strategic value of renewable energies has gone largely unnoticed. Two reasons explain this:

1) An underestimation of their potential to contribute to national energy supply;

2) The belief that renewable energies are much more expensive than fossil fuels.

Numerous studies, projects, and governmental expert commissions (e.g., the *Study Commission on Sustainable Energy Supplies in the context of Globalisation and Liberalisation*, initiated by the German Parliament in 2000) have presented evidence that the potential for renewable energies in combination with energy efficiency measures in Germany and the European Union is large enough to reduce carbon dioxide emissions by 80 percent until 2050. In other words, there are credible substitutes for fossil fuel. This could be accomplished at acceptable prices and would even be beneficial for the national economy if external costs were included (German Bundestag 2002, WWF 2005).

Under the premise of increasing vulnerability, the cost regime of different energy types has to be revised: external costs have to be factored into energy prices. This means that costs arising from energy use—which are not part of nominal energy prices—are included in energy cost calculations. External costs arising from energy use include expenses for repairing environmental damages (local and global), for curing negative health effects, but also for increased security efforts throughout the whole supply chain. Internalizing these costs would lead to a price increase—reflecting "real" energy costs. Under these changing price conditions, the market will need to reexamine the available energy options. It will have to recalculate cost effectiveness.

Factoring in external costs, e. g., for electricity, would shift the cost balance in favor of renewables. High oil and gas prices have already made biomass for heat generation in buildings competitive. Wind power, and especially geothermal energy, is still more expensive than electricity produced from coal or natural gas. The limited time span of technology development—compared with fossil (and nuclear)–explains the current high cost. Nevertheless, costs are converging. Learning in the renewable sector and increasing fossil fuel prices are reducing the price span between renewables and non-renewables.

The once valid maxim of reliable and cheap energy supply—focusing on the German (domestic) market and that of the European Union—has to be broadened to cover more non-energy aspects, as outlined above. Consequently, apart from current cost differences amongst energy carriers, the relevant issues are: can we afford to pay less for electricity from fossil sources facing increasing security challenges? Is the additional price we pay for the reduction of import dependence too high when each unit of domestically produced energy strengthens national negotiation leverage in politically difficult times and immunizes against pressure from energy suppliers?

Our traditional energy systems show structural weaknesses—today more than ever. Muddling through with these systems seems only second best in the light of growing national and international insecurities and vulnerabilities. What is required instead is an energy strategy coordinated among all relevant players leading to courageous decisions and concrete steps enabling the transformation to systems intrinsically less vulnerable.

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