

Indispensable Fossil Energy – Perception and Reality*

Dietrich H. Welte¹

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Translation by Dr. Joseph T. Forrest, Jr., Efland NC (jforrest@resourcegeoservices.com).

¹Emeritus Professor, Ritterstraße 23, 52072 Aachen, Germany. Formerly with RWTH Aachen University, Forschungszentrum Jülich, Jacobs-University, IES Integrated Exploration Systems, Inc (dhwelte5@t-online.de)

Recipient of the AAPG Sidney Powers Award, 2013. [Click to view Dr. Welte's comments upon receiving the Award](#). Note: large file (530 mb) please be patient.

Summary

Indispensable Fossil Energy: Perception and Reality

There is a broad political and social consensus that the provision of primary energy is an important prerequisite for any highly developed industrial nation and that it must satisfy the requirements of the so-called energy triangle, i.e., Security of Energy Provision, Economic Viability, and Environmental Friendliness. However, there is no fact-based agreement in politics or society about how to evaluate the individual corners of the energy triangle. With the so-called “Energiewende” (“*energy reversal*”) and the immediate phasing out of nuclear energy, the availability of primary energy in Germany has become more uncertain. Renewable energy sources are overemphasized and hence detrimental to the development of a realistic, affordable energy strategy. Although fossil energy sources provide about 80% of our primary energy at present, they are supposed to be reduced substantially within one to two decades and replaced with renewables. Cost/benefit considerations and security of energy supplies seem to be of no concern.

The main arguments for this kind of energy policy are: (1) a “foreseeable end to the availability of fossil energy”, (2) the large dependency on imports, and (3) the alleged threats of “global warming” supposedly caused by anthropogenic CO₂ emissions. Argument number one is invalid, because there will be no shortages in reserves or resources of oil, gas, and coal within the next 30+ years (and beyond). The second argument concerning a high import dependency is valid and must be taken care of. However, as experience has shown, measures can be taken to minimize and/or avoid critical situations, for example adequate trade policies and a reinforcement of national fossil energy reserves and resources, such as brown coal, shale gas, and coalbed methane (CBM). The third argument must be critically reviewed. It must be reduced to what it is – a hypothesis based on the results of ambitious numerical simulations of complex climate-related natural processes, many of which are insufficiently understood. In addition, there is no evidence from paleoclimate records that atmospheric CO₂ was the main climate-

controlling parameter. This is in line with the observation that, with increasing atmospheric CO₂ concentrations, global temperatures have been decreasing during the last 10 years.

Germany would be well advised to have a critical fresh look at the very important issue of “energy and climate”. However, regarding the present emotionally charged atmosphere, balancing the energy triangle based on facts is a very complex and delicate task. With respect to the central issue of the role of anthropogenic CO₂, science must clearly tell us what we know for sure and what we do not know.

The academies of science are probably best suited to act as a neutral mediator between politics, media, and society on one side and science, technology, and the economy on the other.

Introduction

The three-pronged tragedy, consisting of earthquakes, tsunami, and the reactor accident, in Japan in March 2011, resulted in a worldwide reassessment of nuclear energy technology. As a result, there was a call in Germany for an „energy reversal“ (“Energiewende”) policy and a decision to rapidly abandon atomic energy. In the complex world of primary energy supply, this reactor accident is a true problem and a challenge, which must lead us to rethink a more realistic position concerning energy supply. Alongside the present and real nuclear energy problem is the further and more diffuse problem related to energy supply that has been seen especially in Germany for decades – the problem of anthropogenic CO₂ emissions from the use of fossil fuels, which serves in the public mind and in official policy as the main cause for global warming and which has become especially touted in the media as the reason for a threatening climatic catastrophe. In this regard we should clarify how this partially polemically- and demagogically-led debate originated and the directions it has taken.

The last, long-term energy strategy for the Federal Republic of Germany was put forth about 40 years ago under the administration of Chancellor Helmut Schmidt. In this strategy, nuclear energy played an important role next to the „classic“ fossil fuels. In the early 1980’s, prior to the reactor catastrophe at Chernobyl (1986), “climate-damaging” anthropogenic CO₂ from fossil fuels became the overriding reason for development of nuclear energy. The same happened in England. In 1987, in a joint worldwide appeal, the German Physical Society (Deutsche Physikalische Gesellschaft = DPG) and the German Meteorological Society (Deutsche Meteorologische Gesellschaft = DMG), warned of impending manmade climate change, based on computer models that pointed to anthropogenic CO₂ as the main culprit.

Official policy was influenced by these announcements, and from that point on, state-financed climate research boomed. It is certainly no accident that, one year later under strong German participation, the United Nations established the „Intergovernmental Panel on Climate Change“ (IPCC). Soon the leading scientific nations had made the best and fastest supercomputers available for climate research. Triumphant march of the computers proceeded faster than the necessary recording of data that was needed to feed the machines and models. Moreover, well-grounded understanding of processes in the chain of action of past and present climate events was lacking and is still lacking today. Founding of the Potsdam Institute for Climate Consequence Research (Potsdam-Institut für Klimafolgenforschung = PIK) and the Scientific Advisory Board of the Federal Administration For Global Environmental Change (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen = WBGU) both occurred in this period (1991 and 1992, respectively).

In the year 1995, a further study from the German Physical Society appeared under that association's "Energy Memorandum 1995"; it carried the title „Future Climate Compatible Energy Use and Political Action Requirements for Market Introduction of New Emission Lessening Technologies.“ In that study it was warned that sea-level rise of around a half meter could be expected due to manmade increase of temperature,” with subsequent disappearance of seven states of the world community”. Also called to attention was the fate of climate refugees from southern countries, “which have the least responsibility for the continuous production of greenhouse gases.”

Such pronouncements from certain parts of the scientific community were greedily consumed by politicians and the media and were orchestrated to their advantage. The approaching climate catastrophe became a fervently followed talk-show theme. German politics and society began to position itself as an international leader in strong climate protection, with no consideration in the debate of cost and benefits. Germany wanted at any price to be the pacemaker in climate protection and de-carbonization of energy supplies. These developments and the topic of „manmade global warming“ had their preliminary high point in the year 2007 with award of the Nobel Peace Prize to the IPCC and to Al Gore, Jr., former Vice President of the United States.

The Future Supply of Primary Energy and the Role of Fossil Energy

There is wide political and societal consensus that supply of primary energy is an important foundation of every industrialized nation and that it must satisfy the criteria of the energy triangle, whose corner points are Security of Provision, Economic Viability, and Environmental Friendliness ([Figure 1](#)). A factual-based understanding required to estimate the value of these corner points still does not exist. The complex field of energy policy is being decided on the one hand by politics, the media, and society and on the other hand by technology, science, and economics ([Figure 2](#)). The present and past situation of German energy policy shows clearly how difficult it is to develop a realistic and future-oriented energy strategy in this area of controversy for the German (and European) position. To begin with, we must disregard ideologies and consider some important facts about primary energy.

Firstly, and most importantly, is recognition of the dominance of fossil fuels ([Figure 3](#)), which even through the phasing out of atomic energy will probably even increase further. The second consideration is the very high dependence of Germany (over 80%) on imports of crude oil and natural gas ([Figure 4](#)). Thirdly, it must be realized that renewable energy sources will not be in place in the foreseeable future to cover the main part of our required supply of primary energy, to say nothing about the economics of their implementation. In the year 2009 the cumulative share of renewable fuels averaged only about 9% of Germany's primary energy needs ([Figure 3](#)), in spite of their ubiquitous public presence throughout the country. There are numerous, principally politically-motivated, studies that tout a high possible share of renewable fuels in the future. However, the most optimistic scenarios place renewables at just over 20% of the primary energy requirement by the year 2030 ([Figure 5](#)) – and this disregards any consideration of costs, benefits, and realistic technology scenarios.

Contrary to perceptions conveyed through the media and politics, with their overemphasis on renewable fuels, Germany and the rest of the world will be dependent in the next decades on massive quantities of natural gas, crude oil, and coal. Without their intensive utilization the position of Germany in global competition, with its high standard of living, will not be sustainable in the next decades. A politically-motivated, overly-hasty further increase in the share of renewables – something on the order of that prescribed in the German Renewable Energy Law (Erneuerbare-Energien-Gesetz = EEG) – will burden German taxpayer's power bill even more than presently. Alone in 2010 the increase in

costs related to „green“ energy amounted to 12.8 billion Euros (Stratmann, 2011). Higher energy costs would weaken the competitive efficiencies of Germany's energy intensive industries. The politically-postulated way to reduce dependence on fossil energy sources is in the long term correct, but, please, with some sense of proportion, realistically, and not with grave consequences for Germany's standing in the world. To find wide consent among the German population (80%) for the previously-mentioned policy of development of renewable energy sources (FAZ, 2011), better consideration should be given to the fact-based reality of the primary energy problem and not the self-generated, specious perceptions spread by politicians and media.

Three main arguments have been put forth to support forced utilization of renewable energy sources and rapid reduction in consumption of fossil energy: (1) a supposedly foreseeable shortage in fossil energy sources (natural gas and crude oil), (2) the German dependence on imports, and (3) the theme of global warming due to anthropogenic CO₂, which has been particularly emphasized.

With regard to the argument of foreseeable shortages of crude oil and natural gas, it should be pointed out that both energy sources are available presently in large quantities, even when measured against today's global usage, which for example in the case of crude oil is around 4 billion tons per year. However, both energy sources will in the distant future be exhausted. An efficient and conservative utilization is absolutely necessary, if for no other reason than resource conservation. In hindsight, the Club of Rome made a blatant mistake in predicting the exhaustion of oil accumulations by the turn of the 21st century (Meadows et al., 1972). Importantly, constant improvements in oil and gas exploration and production technologies and increases in price have contributed to higher production profits, factors that were not considered in the Club of Rome's report. Furthermore, opening of newly discovered sedimentary basins and deeper productive levels, up to 10 km, have increased resource potential considerably. For these and other reasons it is today very difficult to make a meaningful prediction as to the end of the „crude oil age. From a geological perspective, and on the basis of available exploration and production technology, all serious availability-scenarios predict that no lack of crude oil should be expected in the next 30 years ([Figure 6](#)). Revealing in this regard is the increase in proven crude oil reserves since 1980 versus the time span in years necessary to consume these reserves. In the last 20 years the statistical range fluctuated between 35 and over 45 years. There was no sign of a foreseeable shortage then, just as there is none today.

For natural gas there is from both geological and technical points of view a still considerably longer period of resource availability ([Figure 6](#), details in DERA, 2011). Compared to crude oil natural gas has advantages that make it especially attractive in the arena of energy supply. Since its main component is methane (CH₄), and it contains at most only limited admixtures of higher hydrocarbons, and/or carbon dioxide (CO₂), hydrogen sulfide (H₂S) and nitrogen (N₂), it is relatively environmentally friendly. In comparison to other fossil energy sources the burning of natural gas generates little CO₂ and, importantly, more water. Especially interesting from the German and European point of view is the future opening and utilization of unconventional shale gas resources and the coal-bound gas known as coalbed methane. Both varieties of gas are found in Germany and can be exploited to lessen our dependence on imports. For these reasons this gas potential is explored further in the following section.

Unconventional gas accumulations are those that do not occur in high porosity reservoir rocks under a thick sealing layer in a folded structure, but rather in thick, flat-lying shale or in coal-seam deposits ([Figure 7](#)). This type of gas is designated as shale gas or, when it occurs in coal, as coal-bed methane. This unconventional natural gas consists, in a broad sense, of methane and has an identical history of origin as conventional natural gas deposits. The difference between the two types of gases – unconventional and conventional – is that unconventional gas has

remained at its place of origin, that is to say, in shales with a high content of organic matter or in coal seams, including the famous Jurassic Holzmaden shales in the Stuttgart region and the oil shales of the Messel trough, both of which have been named as United Nations World Heritage sites due to their fantastic content of uniquely preserved fossils. When such high-organic shales are buried to great depths they generate natural gases from their organic matter. The same is true for coals. When immature coals, that is to say brown coals, are buried to great depths and become transformed into hard (bituminous) coal, natural gas is generated as a by-product. This type of natural gas, often referred to as mine-gas or colliery gas, is greatly feared in coal mines worldwide because of the danger of explosion.

Both unconventional gas types – shale gas and coal-bed methane – must be developed and produced through expensive procedures. Just as in the crude oil industry, wells have to be drilled. Then under high pressure the host rocks are hydraulically fractured to produce an artificial network of fissures that serves as a conduit for flow and accumulation of the gas. This procedure has been applied worldwide millions of times and is an established standard of drilling technology. The potential resource of unconventional gas is many times greater than that of conventional gas ([Figure 6](#)). Even Germany has a substantial unconventional gas potential, and it can only be hoped that, in the course of a realistic and forward-looking energy strategy under the banner of energy reversal, these resources will be utilized in a meaningful manner. In all European energy portfolios natural gas will be assigned an increasingly important future role as an energy source.

Under fossil fuels coal will also play an increasingly meaningful role globally in the future. After crude oil, coal is the second most important source of primary energy. This is clearly shown in projections of the International Energy Agency (IEA) in that group's New Policy Scenario (Compare [Figure 5](#)). For Germany this is of especial importance from the point of view of avoiding too great a dependence on imports of oil and gas and on grounds of the economics of brown coal. Because of its connection with production of CO₂ the burning of brown coal arouses passionate feelings. We should take the time here to look back critically at the IPCC conclusion that ... "anthropogenic CO₂ is the main cause of global warming."

Energy and Climate

Let's recall the 1980's and the 1990's. Based on the computer models generated during that period the German Physical Society and the German Meteorological Society warned of worldwide manmade climate changes; the IPCC was then founded; and politicians and media seized the topic. The political and media momentum has remained the same, but the fear-raising, catastrophic predictions from the climate-related computer models did not take place. In fact the influence of anthropogenic greenhouse gases on climate change is being substantially overestimated (Malberg, 2012). As a result, the known complex history of the Earth with its changing cold and warm periods as well as the many parameters that determine climate (especially the Sun) should be given much more consideration (Compare Berner and Streif, 2004; Welte and Böcker, 2007; Böcker et al., 2010; Ganteför, 2010; Singer, 2011).

There is neither a worldwide trend to more storms and flooding, nor is there an anthropogenic sign of rising sea level (Puls, 2008). In addition the IPCC has clearly retracted its prediction of rising sea level. Also worth noting is that, despite increasing CO₂ concentrations approaching 400 ppm, the average global temperature in the last 13 years has not risen, but has decreased (Easterling and Wehner, 2009; Scafetta, 2011). At this point we should be concerned about the role of computer models, which have focused principally on the influence of anthropogenic CO₂ at the cost of many other climate-influencing parameters, some of which are not sufficiently understood.

In the context addressed here computer models serve to understand and, as far as is possible, quantify the unusually complex processes of CO₂ transport between the global atmosphere, hydrosphere, biosphere, and geosphere compartments and to relate the effects of the trace gas CO₂ (in association with other greenhouse gases) on the Earth's energy balance, especially on the atmosphere compartment. Prerequisites for this type of modeling are twofold: (1) A very good understanding of each of the involved physical processes and their reciprocal interactions in the process chain, and (2) availability of massive volumes of measured data from around the world to feed the models. Since the understanding of processes overall presents substantial shortcomings, and the data is anything but optimal, many assumptions must be made for the model runs. Anyone who works with complex computer models knows that „a can of worms“ is opened with each assumption that is made. The complexity of climate modeling belongs to the most demanding of the numerical simulations of natural processes. It should be confirmed here that climate research by numerical simulation has made enormous contributions. However, the question in relationship to the theme of Energy and Climate is whether such models should serve as justification for radical surgical treatment to society. The answer to this question should come primarily from science. Although computer models are a very important technique of modern science, it has to be made clear that for the simulation of complex natural processes they are usually near the limit of their capabilities, especially when, as in climate events, chaotic processes are in play. There are simply too many serious uncertainties, as, for example, the following, to name just a few (Compare Hagedorn, 2005):

- Cloud formation in general and the influence of cosmic radiation
- Vapor and energy transport
- Influence of aerosols and other air pollutants
- Thermo-haline circulation in the oceans
- Quantification of CO₂ sources and sinks
- Interaction between CO₂ and water vapor in the infrared spectrum and the problem of saturation (logarithmic decline of the heat effect with increasing concentration of CO₂).

A geologically important point should be mentioned here: the deficiency in quantifying the magnitude of CO₂ transport and mode of action of CO₂ sources and sinks inside, outside, and in between the separate compartments. The degree of error or uncertainty of the quantification of total natural CO₂ circulation (sources and sinks) is on the order of more than $\pm 10\%$. Since the contribution of anthropogenic CO₂ accounts for only 6% of the natural total circulation, a major problem arises in interpreting its effects on climate. Magnitude of the manmade CO₂ effect is blurred in the degree of uncertainty.

In addition to the inherent uncertainty of computer models, one should also realize that the assertion that the present-day CO₂ concentration of 380 ppm in the atmosphere represents an historical record is simply false. Atmospheric CO₂ concentration has fluctuated significantly in the course of the Earth's history, and was mostly higher than today prior to the Miocene/Oligocene periods, that is to say, prior to 20 million years ago (Berner and Streif, 2004; [Figure 8](#)). In the Silurian and on the boundary between the Carboniferous and Permian there were large areas of glaciation, as well as cold periods in the Early Cretaceous, during which CO₂ concentrations were significantly higher than at present. These facts are contrary to the assertion that CO₂ would have had a dominant influence on climate. The magnitude of atmospheric CO₂ content during the course of geological history has been much more significantly influenced by rates of photosynthesis, oxidation of organic material,

volcanism (both land and submarine), solution and degassing in and from the oceans, the binding of CO₂ through silicate weathering, and carbonate formation and solution.

All in all we see that public perception of the role of anthropogenic CO₂ in no way agrees with reality. There are many questions that the public and politicians must be informed on. The politicians must know that the computer models, with so many uncertainties, are not suitable for burdening an entire economy with billions in tax moneys and threatening the country with an unknown future in its global competition.

German Energy Reversal and CO₂ Reduction

A large part of the German energy reversal policy includes abandonment of nuclear energy and a strong push to replace fossil energy sources with renewables. With this objective in mind, all participants should reevaluate the energy triangle ([Figure 1](#)) carefully in light of the above remarks and bring a fact-based balance to the debate. It is obligatory that the facts be delivered from science, technology, and economics. Further, these facts must recognize the known uncertainties about climate change and convey them to politicians and the public in a non-prejudicial manner. Without knowledge of actual facts and without transparent disclosure of the way they have been derived, political accomplishment of a practical energy strategy will not be possible in this controversial German sphere ([Figure 2](#)). A forward-looking, meaningful energy strategy must also be globally oriented.

Important corner points of provision and utilization of primary energy should be recalled here. The very highly subsidized CO₂ reduction policies in Europe, and especially in Germany, are not being followed in most other parts of the world. This includes the trading of CO₂ emissions certificates, in which costs of the reduction of a ton of CO₂ are being evaluated differently by different countries. According to a study commissioned by the Federation of German Industry (Bundesverband der Deutschen Industrie e.V.) the cost in Germany of the reduction of one ton of CO₂ through biofuels, solar panels, or wind energy is around, or in excess of, 100 Euros (McKinsey, 2007). The burden for the German taxpayer and for the general economy amounts to many billions of Euros. Accordingly, one should keep in mind that Germany is already one of the most energy efficient countries of the world, and that its discharge of manmade CO₂ accounts for only around 3% of the worldwide total. Since CO₂ emissions are increasing worldwide, and the largest emitters – USA, China, and India – are doing little or nothing to reduce their anthropogenic CO₂, Germany, with its unique and exaggerated scale of reduction, stands at a lonely guard post. The message that we can derive is that the overly-hasty increase in the share of renewable energy sources is meaningless, especially if it is not based on rigorous analysis of cost and utilization and a serious balance of greenhouse gases. The expensive nonsense of biofuels planted on agricultural lands, which the European Environmental Agency is criticizing, should be a lesson to us. Indiscriminate over-promotion of solar energy is a further negative example.

From the above remarks we can see the necessity of reevaluating the value of the Environmental Friendliness corner of the energy triangle, a rational balancing of which will result in clear relief for the Economics corner-point and an increase in importance of the Supply Security corner.

Energy Reversal and the Controversial German Energy Policy: What Is to Be Done?

As we have learned, warning signs from the scientific community (DPG and DMG, 1987; DPG, 1995) in the 1980's and 1990's of manmade global warming and potential catastrophic consequences for mankind have led to an overreaction from politicians, media, and society. The activism that has subsequently been set loose for climate protection and intervention in the energy economy has within a few years forcefully overtaken the contributions of science, which was searching for facts and clues for such looming climatic catastrophe. From the beginning till today the scientific community has been divided into „greenhouse theoreticians“ and „climate skeptics,“ whereby the former have dominated the debate. Consequently, it is no wonder that politics and society are united in their belief in manmade climate change. But the very problematic and complex scientific background for this „mainstream belief“ is understood by very few. Clearly stated, policy in energy transition matters is being decided more by intuition and half-knowledge than by natural science and technical and economic facts and thought ([Figure 2](#)). The critical scientific voices in the theme of manmade global warming are being suppressed more and more in public discussion or polemically attacked.

In the name of a practical and meaningful energy policy, a more bearable way, based on facts and realistic possibilities, must be found to assure our society a robust and affordable energy supply and guarantee, at the same time, careful attention to necessary environmental considerations. In the present sphere of controversy what is required is a believable and neutral mediator or arbitrator. This role could and should be served for instance by national Academies of Science ([Figure 9](#)), comprising expertise in different fields of science, technology, and economics. Thoughts of political correctness should be set aside and concentration should be on factual objectives, which are to focus on the balancing of the energy triangle. This will involve three important questions:

1. What should a secure, affordable and robust energy supply look like?
2. How can the mistaken allocation of many billions of German tax moneys for falsely understood globally operative climate protection be prevented or at least reduced?
3. How can we inform the public in a credible way about realities in matters of energy and climate?

Conclusions

Finally, the following assertions and suggestions can be made:

- Worldwide reserves and resources allow that Germany can and will for decades to come utilize fossil energy sources. Supply security and economics can only be guaranteed for the foreseeable future by intensive further utilization of fossil fuels.
- All meaningful measures to conserve the use of fossil fuels should be used, including further development of renewable energy sources. Cost effectiveness and utilization planning, though, must be more strongly considered.
- Uncertainties in computer models and the present understanding of manmade CO₂ to which they have led – as the principal drive of climate change, as well as the meaningless two-degree limit for the saving of the world climate, demand a reorientation in climate protection and the beginning of a new energy strategy. Science must be transparent and upfront in matters of climate and CO₂ in order to finally let society know what is actually understood and what is not.

- The presently published German energy reversal policy leaves many questions open. It must be planned and thereafter implemented with speed and necessary transparency, but with a sense of proportion and a sense of reality for timely and technical feasibility, for economics, and for cost/benefit relationships.
- Intentional adaptations to climate change are significantly more meaningful than the crudely meaningless „German measures“ for preventing a climatic catastrophe. Adaptions are, though, in no way a replacement for the urgent, necessary balancing of the energy triangle. This balancing is a common task for policy, economics, and science.

Afterword

In regard to the above discussion of energy and climate, I want to add several personal remarks. Since the 1970's and my publication entitled "Organic Carbon and the Development of Photosynthesis on Earth (1970, *Naturwissenschaften*, v. 57, p. 17-23), I have devoted especial attention in my professional career as an earth scientist to the themes of carbon cycle and quantification of complex geo-processes. Later, in addition to the topic of fossil energy sources, the numerical simulation of complex geo-processes was one of my areas of greatest interest. Through my activities at the Jülich Research Center (Forschungszentrum Jülich), previously known as the Nuclear Research Institute (Kernforschungsanlage), I was occupied directly or indirectly since the 1980's with the complex subject of energy and climate. The initial purely scientific and technical discussions there became gradually politicized and influenced strongly by the media, thus leading to the present „mainstream“ thesis of anthropogenic CO₂ as the main culprit of global warming. Independent, critical voices from the scientific community were not welcome.

The present intended energy reversal policy in Germany gives this topic an especial volatility, with potential deep fissures in the economic strength and structure of our society. One of the main causes for marking and targeting energy transition policy is the topic of manmade CO₂ as the main cause of global warming, the scientific grounds of which stand in no way on steady legs. It goes without saying that modern National Academies of Science, which are independent and should be obligated to scientific objectivity, should inform politicians and society of their knowledge and advise them on questions of the structuring of the future of our country. From my retrospective experience concerning the theme of energy and climate, this has not yet been the case with the necessary, critical distance and objective scientific breadth. The critical influence of academies as neutral, legitimate mediators in such an important and complex subject is absolutely necessary for reasons of societal responsibility. Considerably more tax moneys are being given out presently for the controversial and often unfulfilled requirements of „green energy“ than are being given to all of our nation's universities. Such a gross imbalance in the utilization of German tax moneys for the securing of the future of our land must not become the normalcy and definitely demands correction.

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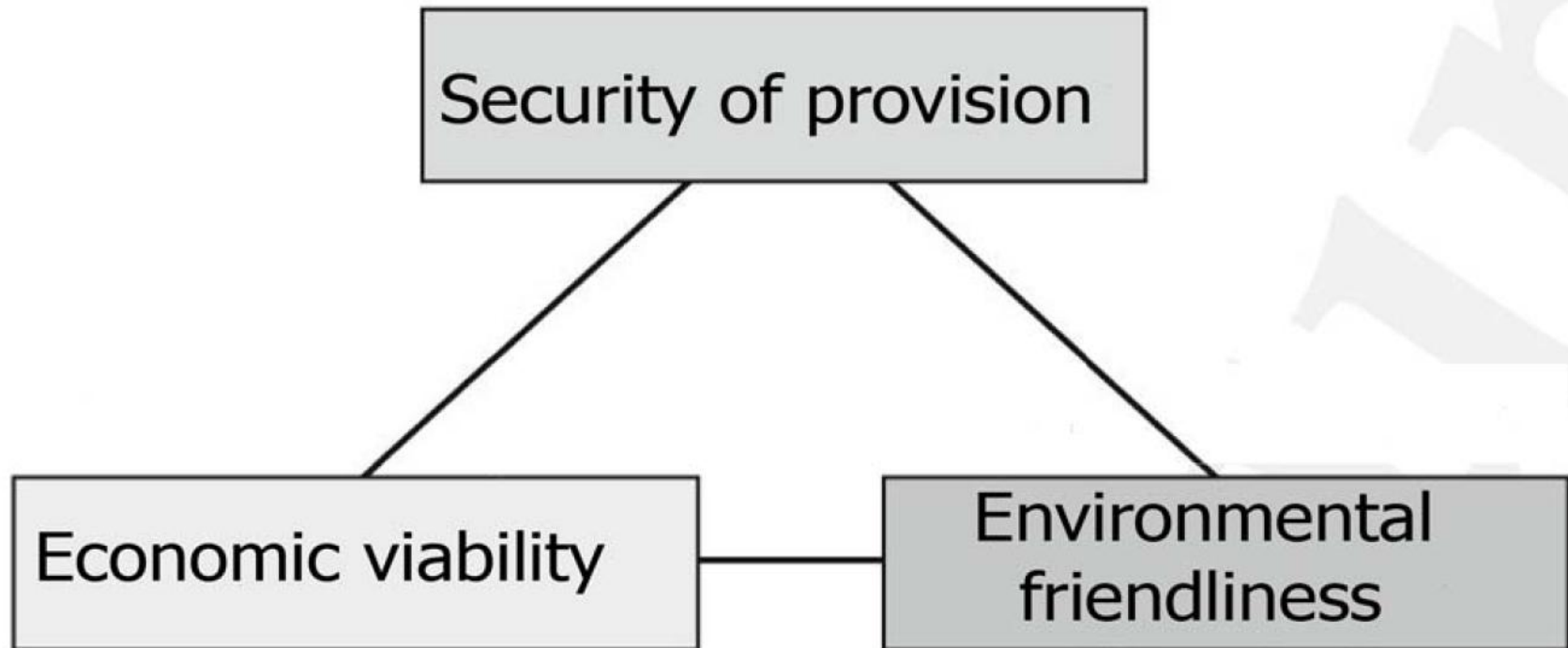


Figure 1. Energy triangle. For provision of primary energy, the triangle should be in balance.

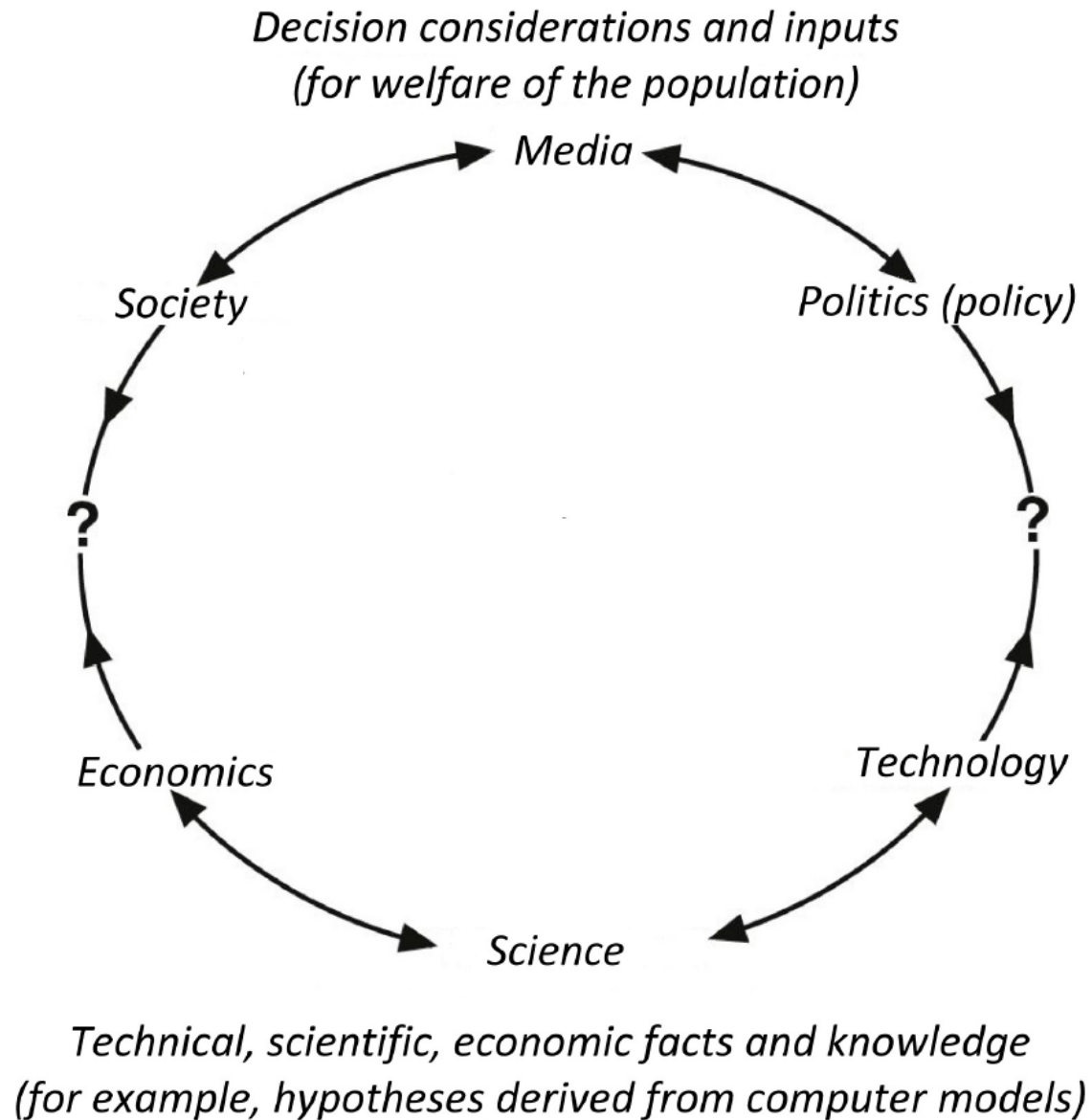


Figure 2. German energy policy in the controversial sphere between society, media, and politics on the one hand and technology, science, and economics on the other.

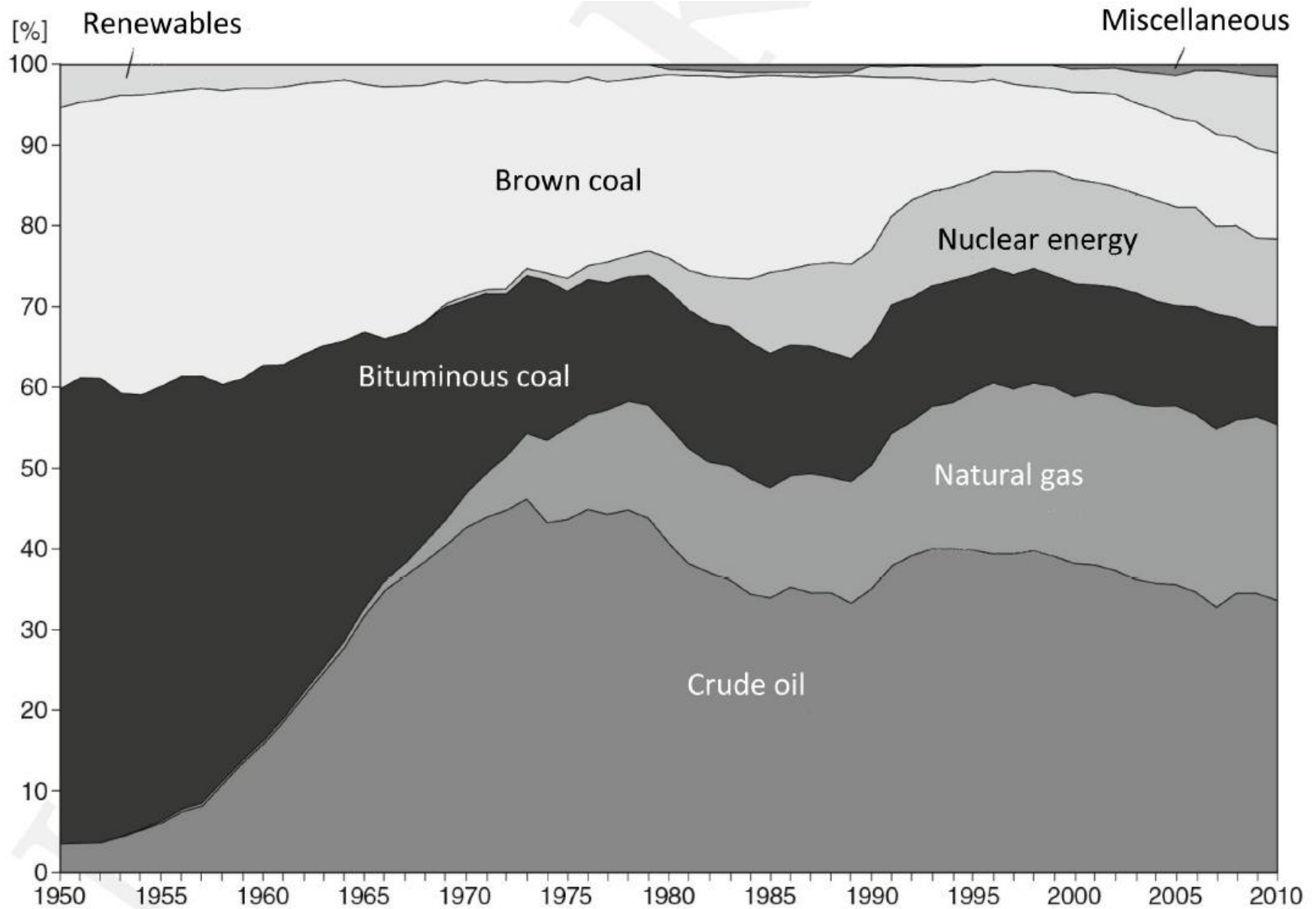


Figure 3. Share of various energy sources (in %) in Germany's primary energy requirements (from BGR, AG Energiebilanzen).

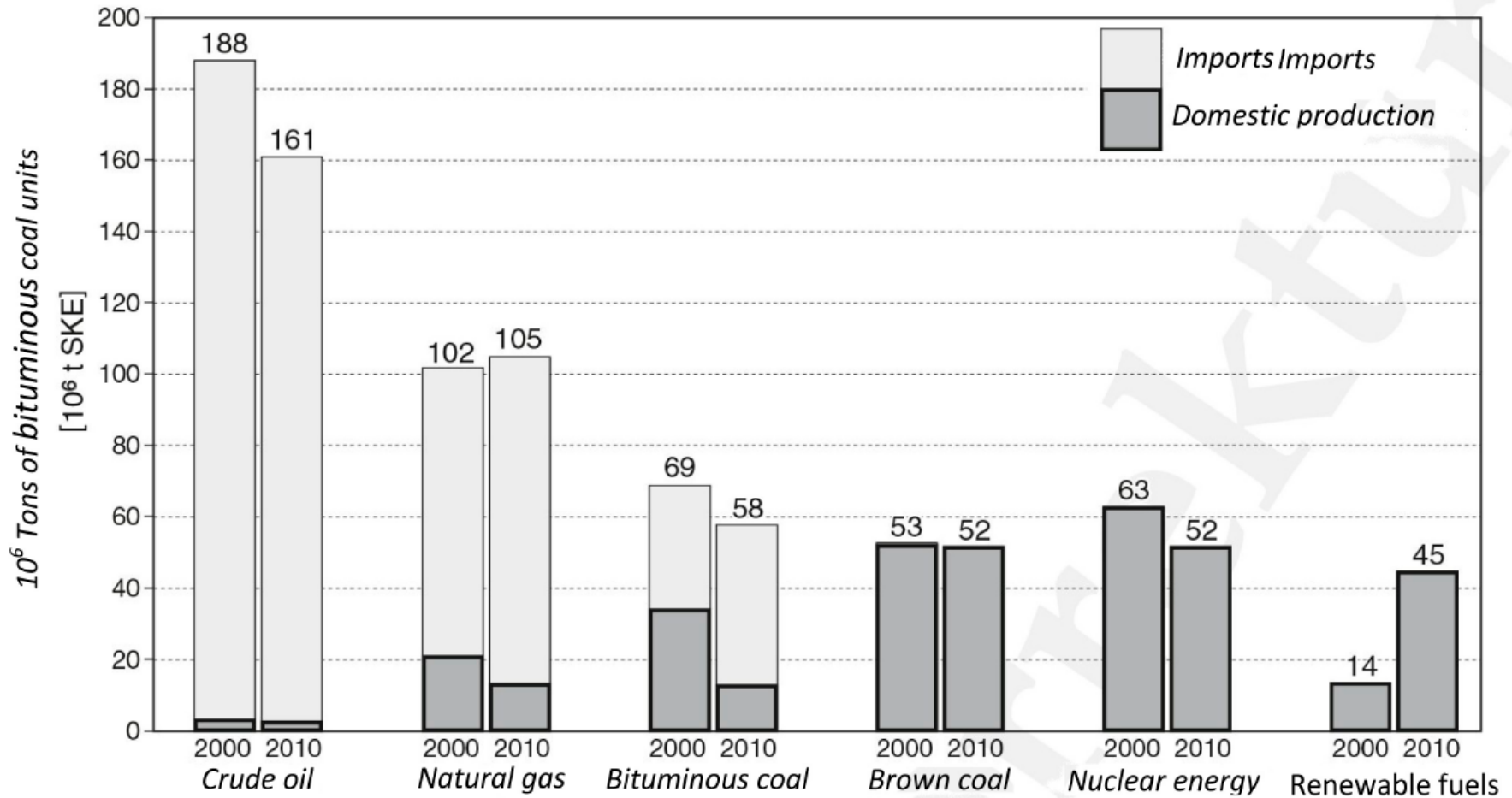


Figure 4. Domestic production and imports of various German fuels (in millions of tons of bituminous coal units/year) for years 2000 and 2010 (source DERA, 2011).

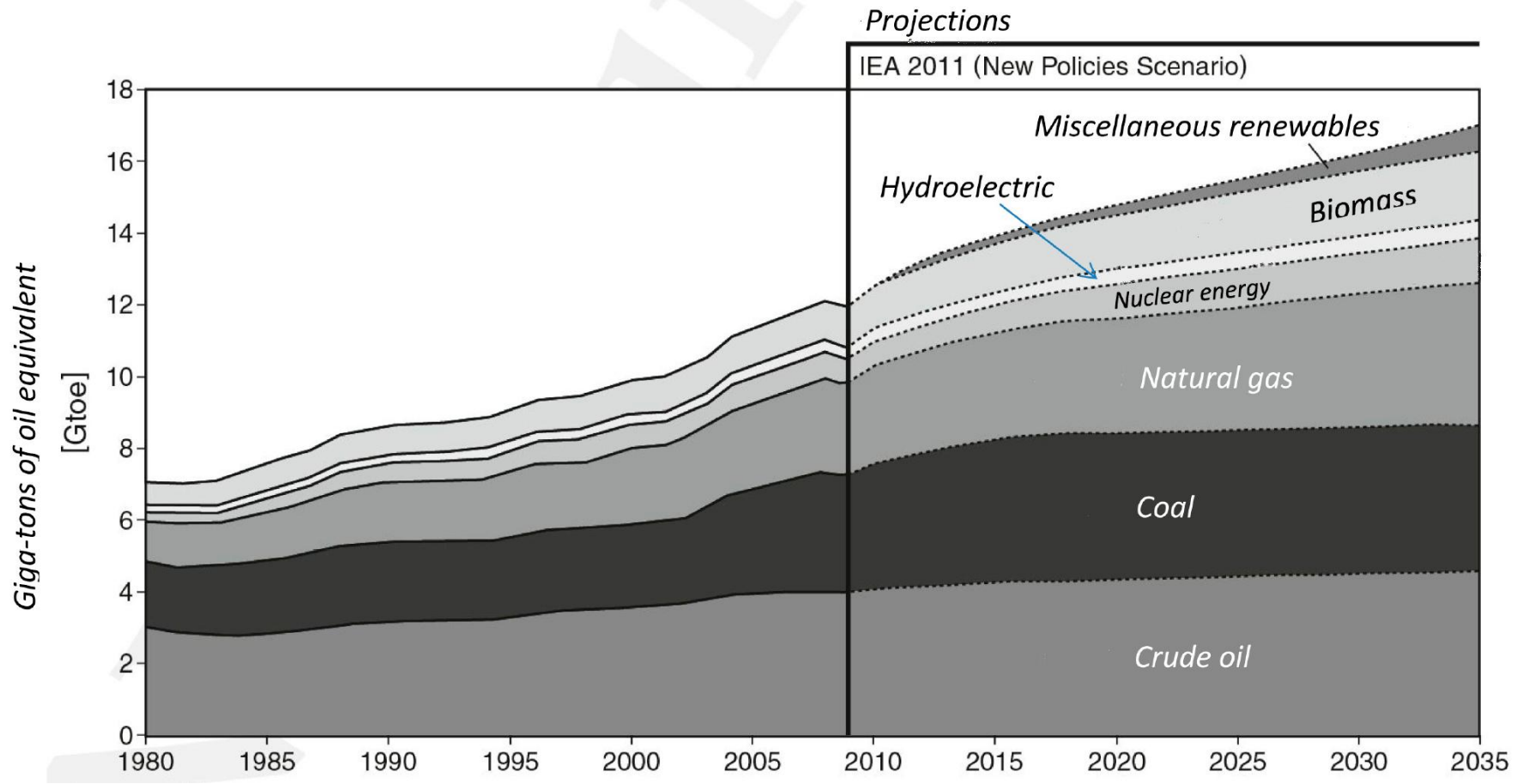


Figure 5. Global primary energy requirements by fuel types (in giga-tons of oil equivalent) since 1980 and projections into the future (source DERA, 2010, 2011; IEA, 2011).

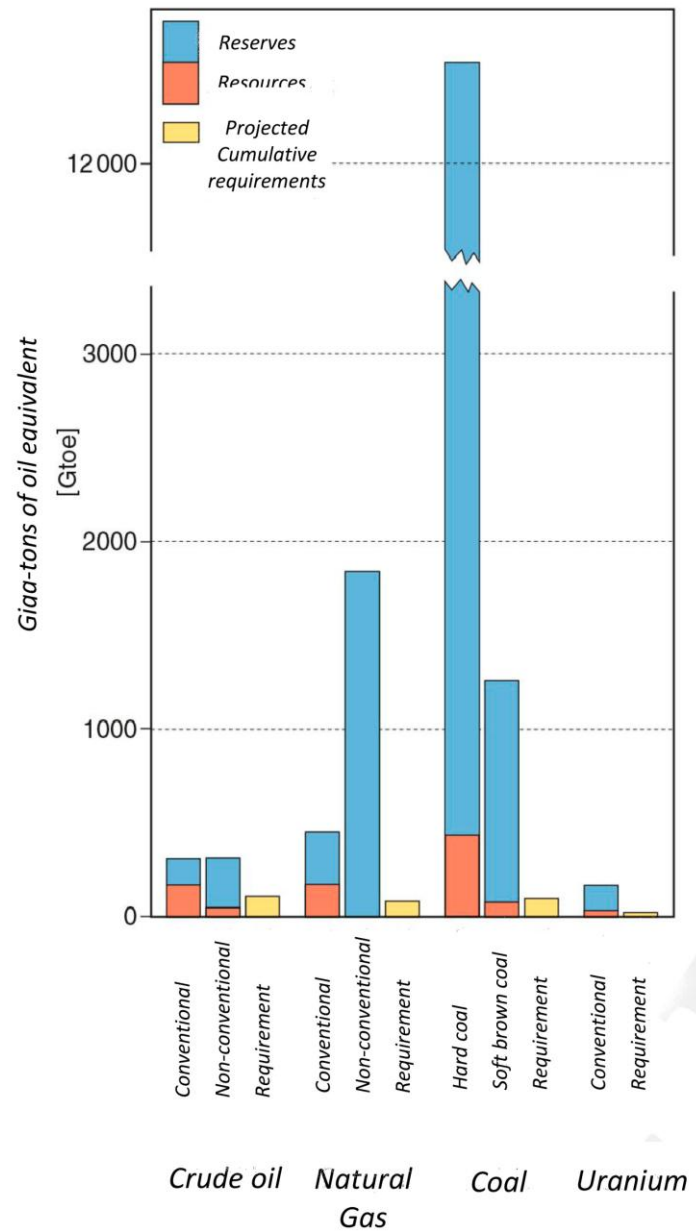


Figure 6. Energy reserves and resources, as well as forecasted cumulative requirements for the period 2011-2035 (in giga-tons of oil equivalent (sources DERA, 2011; IEA,2011)).

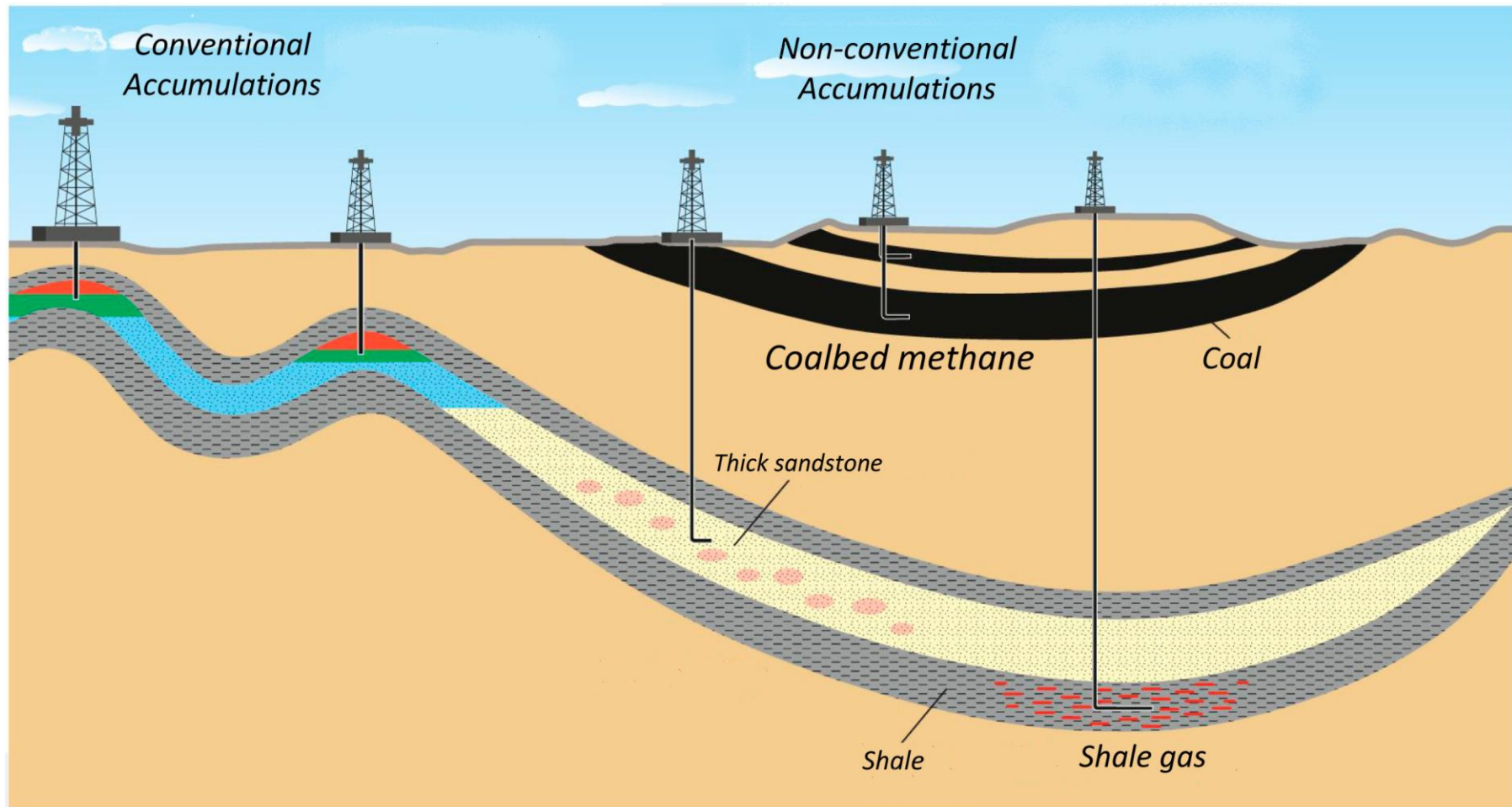


Figure 7. Illustration of the occurrence of conventional and non-conventional natural gas (source BGR).

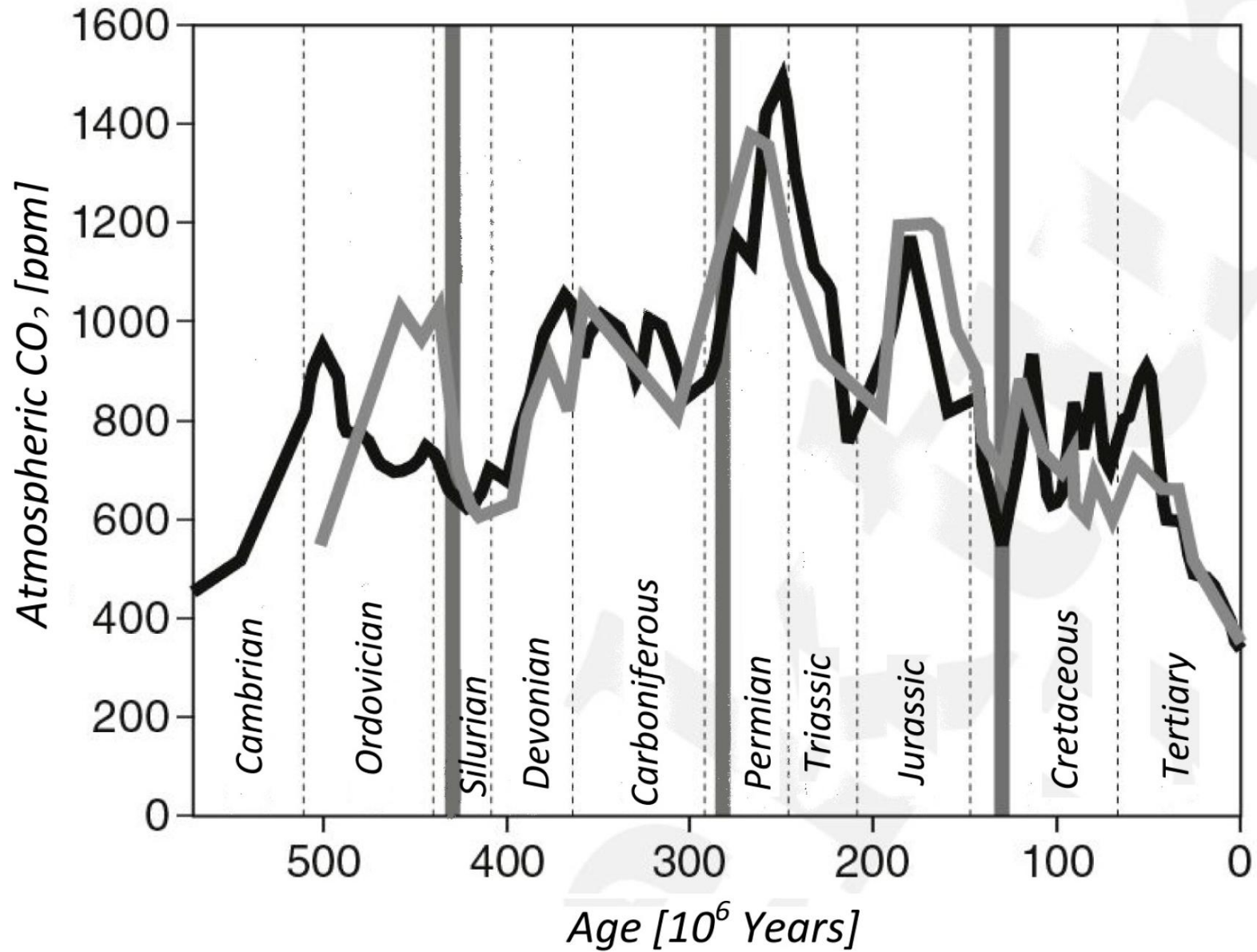


Figure 8. Two examples of reconstructions (ages in millions of years) of earlier atmospheric CO₂ concentrations (CO₂ atm. in ppm) and major glacial and cold periods of higher CO₂ concentrations than today (after Berner and Steif, 2004).

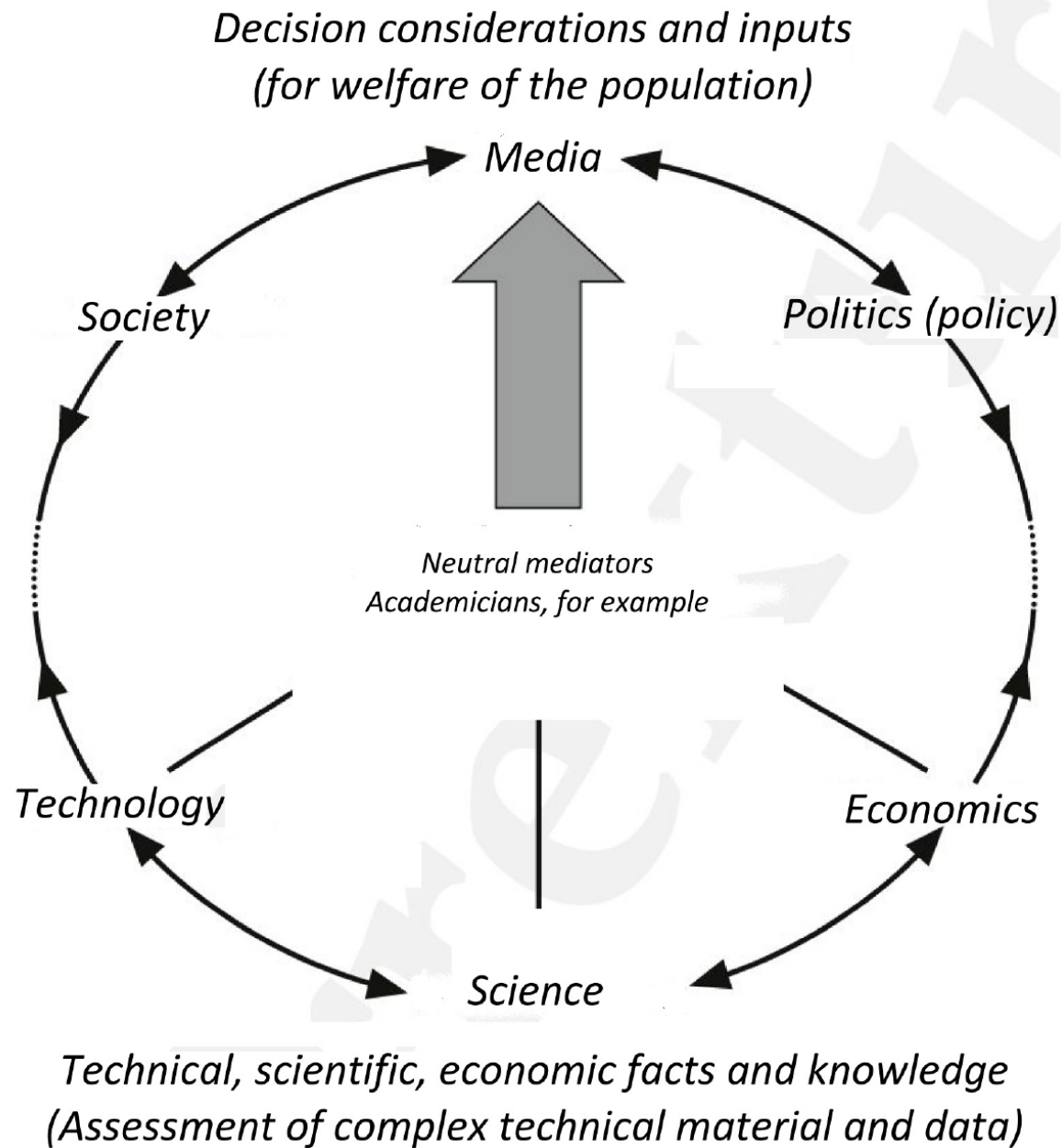


Figure 9. German energy policy in the sphere of controversy: meaning of neutral mediators (compare with [Figure 2](#)).