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Measuring energy security: a conceptual note

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A Conceptual Note

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Measuring Energy Security – A Conceptual Note

Abstract
Along with the oil price, concerns about the security of energy supply have soared once again in recent years. Yet, more than 30 years after the OPEC oil embargo in 1973, energy security still remains a diffuse concept. This paper conceives a statistical indicator that aims at characterizing the energy supply risk of nations that are heavily dependent on energy imports. Our indicator condenses the bulk of empirical information on the imports of fossil fuels originating from a multitude of export countries as well as data on the indigenous contribution to the domestic energy supply into a single parameter. Applying the proposed concept to empirical energy data on Germany and the U.S. (1980–2004), we find that there is a large gap in the energy supply risks between both countries, with Germany suffering much more from a tensed energy supply situation today than the U.S.

JEL Classification: C43, Q41

Keywords: Herfindahl index, energy supply risk indicator

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1 Introduction

The security of energy supply has again become a similarly hot topic as it was during the oil crises in the 1970s. Apparently, the urgency of this issue rises and falls with the price of oil. In recent years, the oil price has reached new historical peaks, being the result of a less palatable buffet of geopolitical conflicts, violent weather conditions, and other disruptive factors on the one hand and a demand increase pushed by a strong global economic development on the other. The confluence of continuing instability in the Middle East and a surge of oil demand in transition and development countries, particularly of China, has made energy supply security a high policy priority in both the European Union and the U.S. Fears about future energy supply are additionally supported by considerations on the establishment of a cartel of gas exporting countries akin to the Organization of Oil Exporting Countries (OPEC).

Yet, more than 30 years after the OPEC oil embargo in 1973, energy security still remains a diffuse concept (CHALKER 2006:119). There appears to be neither a clear and unique definition nor a widely accepted statistical measure that captures the notion of energy security. This deficit seems to be all the more surprising as resource economics has a long tradition that is based on the classical contributions by JEVONS (1865), GRAY (1914), and HOTELLING (1931). Partly, this may be the result of the difficulty to incorporate diverse resource economic aspects, such as absolute and relative scarcity, into a single indicator. While the notion of absolute scarcity focuses on the potential exhaustion of resources such as oil or gas, the aspect of relative scarcity captures transient resource shortages, for instance due to missing supply capacities. Without such an indicator, however, any objective judgement on the security of raw materials supply is hardly possible.

Taking on the perspective of nations that are heavily dependent on energy imports, such as the U.S. and Germany, this paper conceives an energy supply risk indicator that focuses on the aspect of relative scarcity and allows for cross-country and inter-temporal comparisons of the energy security situation of import countries as well as counterfactual analyses of alternative policy scenarios (FRONDEL, SCHMIDT 2006).

Our focus on the aspect of relative, rather than absolute scarcity is due to the fact that the eventual exhaustion of energy resources, such as oil and gas, is not yet virulent (Gordon 2005:122-123). Similarly, unlike GRAY (1914) and HOTELLING (1931) more recent contributions to the resource economics literature such as ADELMAN (1990, 1993) and GORDON (1967) are based on the assumption that the exhaustion of resources does not bear any binding restriction.

The proposed risk indicator aims at condensing the bulk of empirical information on the imports of fossil fuels, such as oil, gas, and coal, originating from a multitude of export countries as well as data on the indigenous contribution to the domestic supply of all kinds of energy sources, including biofuels and other renewable energies. Our concept's empirical outcome is a single figure that characterizes the total risk of a country's reliance on fossil fuel imports at a given point of time. While taking account of all energy sources used in a country, both renewable and non-renewable, the basic ingredients of our concept are a country's own contribution to the total domestic supply of any fuel, the fuels' import shares, and the probabilities of supply disruptions in export countries. The conceived risk indicator is essentially a weighted average of fuel-specific risks, with the weights being the relative contribution of a fuel to the overall energy supply in a country, including domestically produced fossil fuels as well as biofuels and renewable electricity and heat generation. Most importantly, the indicator is able to take account of the fact that an export country's oil supply disruption may be correlated with those of other fossil fuels. The Iran, for example, is among the most important oil and gas producing countries, implying serious oil as well as gas supply shortages in case of potential political conflicts.

The following section elaborates on a statistical indicator of energy security. In Section 3, the proposed concept is applied to empirical energy data on Germany and the U. S (1980-2004), which is provided by the International Energy Agency (IEA). The results indicate that the current supply situation is much more relaxed for the U. S. than for Germany. The last section summarizes and concludes.

2 Measuring Energy Security: An Empirical Concept

Designating the share of export country j in the domestic supply of energy resource i by x_{ij} and the respective indigenous contribution by x_{id}, it is:

$$x_{id} + x_{i1} + ... + x_{ij} + ... + x_{iJ} = 1, \quad i = 1, ..., I. \tag{1}$$

Denoting the probability of supply disruptions in export country j by r_j, we suggest the following quadratic form as a measure capturing a nation's supply risk related to fuel i:

$$\text{risk}_i := \mathbf{x}_i^T \cdot \mathbf{R} \cdot \mathbf{x}_i = x_{id}^2 \cdot r_d + \sum_{j=1}^{J} x_{ij}^2 \cdot r_j. \tag{2}$$

The risk-characterizing matrix $\mathbf{R}$ is defined by $\mathbf{R} := \mathbf{r}^T \cdot \mathbf{I}$, where $\mathbf{I}$ is the identity matrix and $\mathbf{r}^T := (r_d, r_1, ..., r_j, ..., r_J)$ may be denoted as risk vector. Essentially, the probability of a disruption of a nation's own contribution to the domestic supply can be assumed to equal zero: $r_d = 0$.

From the perspective of an import country, the components of share vector $\mathbf{x}_i$ defined by $\mathbf{x}_i^T := (x_{id}, x_{i1}, ..., x_{ij}, ..., x_{iJ})$, are the primary instruments to improve supply security. If x_{id} equals unity, a nation is autarkic with respect to fuel i. In this polar case, the supply risk related to fuel i, as defined by (2), takes on the minimum value of zero, indicating a perfectly secure fuel supply. In the opposite polar case, in which the total supply of fuel i exclusively originates from highly instable export countries such that $r_j = 1$ for all countries $j = 1, ..., J$, risk$_i$ takes on the maximum value of unity. In short, the fuel-specific risk defined by (2) is normalized: $0 \leq \text{risk}_i \leq 1$ (for a proof of this proposition, see Appendix A).

Defining the fuel-specific risk via a quadratic form implies that the risk contribution of an export country j that provides for only a small fraction of, say, x_{ij} = 3 % of the domestic supply is rather negligible. The weight x_{ij}^2 of such a country in expression (2) is as low as .0009. This seems to be sensible, as in practice export countries with such a small contribution to the domestic supply should be quite irrelevant for a nation's energy security situation. Furthermore, increasing diversification by splitting up the imports originating from a single country so that the same amount is then imported from several countries with the same risk characterization reduces the supply risk.

Definition (2) thus comprises three major aspects of energy security: (1) a country's own contribution x_{id} to the total domestic supply of fuel i (2) the political and economic stability of export countries as captured by risk vector $\mathbf{r}$, and (3) the diversification of imports as reflected by vector $\mathbf{x}_i$. The aspect of diversification is incorporated in the fuel-specific indicator risk$_i$ in that it builds on HERFINDAHL's (1950) index with which one can measure the concentration of fuel imports[1]:

$$H_i := s_{i1}^2 + ... + s_{ij}^2 + ... + s_{iJ}^2, \tag{3}$$

where s_{ij} denotes the share of export country j in total imports of fuel i. The share s_{ij} relates to country j's contribution x_{ij} to the total domestic supply of fuel i as follows:

$$x_{ij} = s_{ij}(1 - x_{id}). \tag{4}$$

According to this expression, increasing the indigenous contribution x_{id} decreases x_{ij}, thereby alleviating the import dependency with respect to fuel i and, hence, risk$_i$.

If $\mathbf{R}$ is defined by $\mathbf{R} := \mathbf{r}^T \cdot \mathbf{I}$, a tacit assumption underlying risk definition (2) is that supply disruptions are uncorrelated among export countries, implying that the existence of the OPEC is ignored. To take account of cartels of export countries, the risk matrix $\mathbf{R}$ must be slightly amended by employing the following risk probability matrix:

$$\mathbf{R}_{\text{cartel}} := \begin{pmatrix} 0 & 0 & 0 & . & . & . & 0 \\ 0 & r_1 & 0 & . & . & . & 0 \\ . & . & . & . & . & . & . \\ 0 & 0 & 0 & . & r_c & . & r_c \\ . & . & . & . & . & . & . \\ 0 & 0 & 0 & . & r_c & . & r_c \end{pmatrix}, \tag{5}$$

where the cartel discipline is characterized in this matrix by a common disruption probability r_c. The block emerging in this matrix reflects the correlation of supply disruptions among cartel member countries. In effect, this amendment amounts to treating all

[1]An alternative to the HERFINDAHL's index for measuring diversification is a measure proposed by SHANNON (1948): $S_i = \sum_j s_{ij} \cdot \ln s_{ij}$. We have deliberately refrained from basing our risk indicator on SHANNON's measure, as such an indicator cannot be normalized. The reason is that the maximum of S_i is given by $\ln J$ and increases with the number J of export countries.

cartel members as a single country, whose share is the sum of the members' individual contributions x_{ij}. In principle, therefore, the case of supply disruptions in which several export countries are involved at the same time bears no fundamental difficulty and does not corrupt definition (2).

Thus far, we have focused on a single fuel i, whose supply situation is characterized by risk$_i$. To measure a nation's entire vulnerability with respect to all kinds of energy imports, we suggest evaluating the following generalization of the fuel-specific supply risk defined by (2):

$$\text{risk} := \mathbf{w}^T \cdot \mathbf{X}^T \cdot \mathbf{R} \cdot \mathbf{X} \cdot \mathbf{w} = \mathbf{w}^T \cdot \mathbf{\Pi}^T \cdot \mathbf{w}. \tag{6}$$

$\mathbf{w}^T := (w_1, ..., w_i, ..., w_I)$ represents a vector whose non-negative components w_i reflect the shares of the various fuels and energy sources in a nation's total energy consumption and, hence, add to unity: $w_1 + ... + w_I = 1$. The columns of matrix $\mathbf{X}$ comprise the indigenous as well as the export country's contributions to the domestic supply of each of the I fuels and energy sources:

$$\mathbf{X} := \begin{pmatrix} x_{1d} & . & x_{id} & . & x_{Id} \\ x_{11} & . & x_{i1} & . & x_{I1} \\ . & . & . & . & . \\ x_{1j} & & x_{ij} & & x_{Ij} \\ . & . & . & . & . \\ x_{1J} & . & x_{iJ} & . & x_{IJ} \end{pmatrix} = (\mathbf{x}_1 ... \mathbf{x}_I) \,. \tag{7}$$

The diagonal elements π_{ii} of the product matrix $\mathbf{\Pi} := \mathbf{X}^T \cdot \mathbf{R} \cdot \mathbf{X}$ are identical to the fuel-specific supply risks: $\pi_{ii} = \text{risk}_i = \sum_j^J x_{ij}^2 r_j \geq 0$. Non-vanishing off-diagonal elements, $\pi_{kl} = \sum_j^J x_{kj} x_{lj} r_j > 0$ for $k, l = 1, ..., I, k \neq l$, take account of the fact that, for instance, oil supply disruptions in an export country may be correlated with those of gas. It bears noting that the total supply risk (6) is normalized, as is intuitive and proven in Appendix A: $0 \leq \text{risk} \leq 1$.

3 Empirical Application

Based on energy data provided by the International Energy Agency (IEA), we now employ both the fuel-specific as well as the overall supply risk indicators to compare Germany's and the U. S. inter-temporal changes in the energy supply risk during the period 1980 through 2004. The selection of this period, being due to data availability, allows us to examine both country's reactions to the oil price crises of the 1970s, where the first can be traced to the OPEC oil embargo in 1973, while the second was the result of the Iranian Revolution in 1979 and the subsequent first Gulf war between Iran and Iraq in 1980. The probabilities r_j of supply disruptions in individual export countries are identified here by the OECD classifications displayed in Table B1 of Appendix B. These country-specific classifications, which have been slightly modified to lie within the range of zero to unity, are commonly used to gauge loan loss risks, but also to characterize a country's political and economic situation[2].

Starting with oil, the still most important fossil fuel both in Germany and the U. S. (Table 1), we find that both country's supply risk has roughly doubled – in terms of our fuel-specific indicator – between 1980 and 2004, implying a substantially increasing gap (see Figure 1). A major reason for this finding is that Germany's reliance on Russian oil has risen dramatically since the end of the 1970s. At present, Russia is, by far, Germany's most important oil provider, being responsible for as much as about 40% of total oil supply (see Table B2). That Germany suffers much more from today's tensed oil supply situation than the U. S. is due to the fact that the substantial decline in the U. S. oil production to only a third of the domestic supply has been almost outweighed by intensified imports from stable countries such as Canada and Mexico (see Table B3).

A pattern similar to that for oil can be observed for both country's natural gas supply risks (see Figure 2). While the moderate reduction of the indigenous share in the U. S. gas supply has been balanced by extending the imports from Canada, in the end stabilizing the U. S. gas supply risk at the negligible level of the 1980s, the drastic decli-

[2]These classifications are assumed here to be inter-temporally constant, an assumption that should not be consequential, as the classification of an individual country hardly changes over time.

ne of Germany's relative contribution to its domestic gas supply has been encountered by surging gas imports from Russia. Currently, the contribution of Russian pipelines to Germany's gas supply amounts to about 35% (see Table B4) and, hence, is almost as high as Russia's oil supply share. By contrast, Russian gas played only a minor role for Germany in the 1970s. These fundamental changes and Russia's dominance in both the German oil and gas procurement are all the more disconcerting as the significance of gas has substantially risen: The share of gas in Germany's primary energy supply mix increased from 14.2% in 1980 to 22.6% in 2004 (Table 1).

Figure 1: Crude Oil Supply Risks in Germany and the U. S. (1980-2004)

In contrast to gas, whose consumption as well as imports have been growing since the 1970s, Germany's abundantly available brown coal has lost relative significance. Its share in the primary energy supply mix shrank from 21.7% in 1980 to only 11.9% in 2004 (Table 1). Another domestic energy source, the German hard coal, experienced a decline due to the widening gap between domestic production cost and world market prices of coal (FRONDEL, KAMBECK, SCHMIDT 2007). Yet, despite its increasing economic disadvantages, the indigenous contribution to the hard coal supply in Germany only decreased from about 85% in 1980 to some 40% today (Table B4). By contrast, renewable energy technologies such as wind, solar, and hydro power are still of minor importance for supply security, although these technologies receive strong financial support in Germany.

Figure 2: Natural Gas Supply Risks in Germany and the U. S.

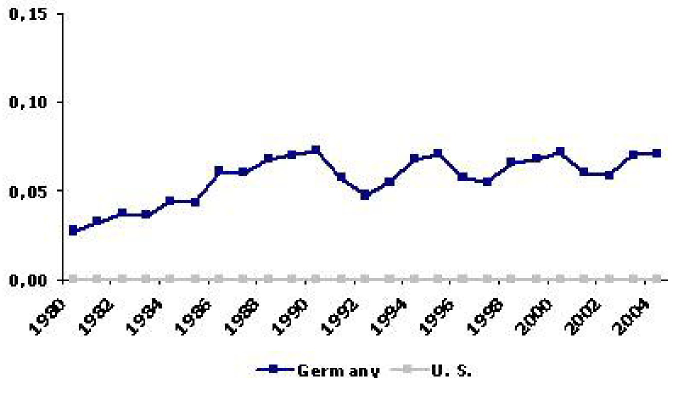

Table 1: Primary Energy Supply Mix in % in Germany and the U. S.

	U. S.				Germany			
	1980	1990	2000	2004	1980	1990	2000	2004
Oil	44.4	40.0	38.7	40.7	40.8	35.5	38.3	35.9
Hard Coal	20.0	22.5	22.6	22.5	17.5	15.5	13.4	12.7
Gas	26.3	22.8	23.8	22.1	14.2	15.4	20.9	22.6
Nuclear	3.8	8.3	9.0	9.1	4.0	11.2	12.9	12.5
Brown Coal	0.8	1.3	1.0	1.0	21.7	20.6	11.3	11.9
Hydro	1.3	1.2	0.9	1.0	0.5	0.4	0.5	0.5
Other sources	3.4	3.9	4.0	3.6	1.3	1.4	2.7	3.9

Note: Calculations are based on IEA (2006c, 2004d, 2006d). Other sources include solar, tide, wind power, etc.

While this also holds true for the U. S. , there is hardly any reliance on foreign hard coal, aside from oil and gas the most important fuel (Table 1). In short, with the increase in nuclear power, which has partially compensated the declining share of domestic oil in the U. S. primary energy supply since the 1980s, and a very low dependence on gas and hard coal imports from instable countries, the U. S. energy security situation appears to be much better than in Germany. This qualitative conclusion is substantiated by the calculation of the total supply risk indicator, whose inter-temporal changes are displayed in Table 2.

In terms of our risk indicator (6), Germany's energy supply risk is about seven times higher than the U. S. risk. While it roughly doubled between 1980 and 2004 in the U. S., above all due to the doubling of the oil-specific supply risk in this period, it more than doubled in Germany. In addition to the increase in the oil-specific supply risk, the reason is the growing dependency from hard coal and, most notably, gas imports.

Table 2: Total Energy Supply Risks in Germany and the U. S.

	1980	1990	2000	2004
Germany	100.0	101.0	173.5	230.1
U. S.	16.2	15.6	27.2	33.8

Note: All values refer to the situation in Germany in 1980.

The inter-temporal picture appears to be somewhat different if the OPEC cartel is taken into account in calculating total supply risks (Table 3) and all OPEC members are uniformly characterized as highly instable countries, building a single block of oil exporters. Attributing the maximum risk of $r_c = 1$ to all OPEC members indicates that Germany heavily relied on OPEC oil in 1980, but as well as the U. S. has reduced this dependency substantially in the aftermath of the oil crises. Since 1990, however, the U. S. energy risk has again increased, because the relative significance of the U. S. oil productions has shrunk dramatically (Table B3). In contrast, the energy risk remained quite stable in Germany between 1990 and 2004, most notably because the OPEC's oil supply share decreased from about 40% to slightly less than 20%, whereas Germany's reliance on Russian oil imports has almost doubled, to some 40% in 2004 (Table B2).

Table 3: Total Energy Supply Risks in case of a Strict OPEC Cartel Discipline

	1980	1990	2000	2004
Germany	100.0	41.2	40.7	41.9
U. S.	25.3	17.2	24.4	30.2

Note: All values refer to the situation in Germany in 1980.

The calculations presented in both Tables 2 and 3 are based on the grounds that nuclear fuels are treated here as a domestic fuel, as well as renewable energy sources. The explanation for this setting is that, in practice, nuclear fuels are frequently imported in times when prices are low and stored up to several decades before used in nuclear power plants.

4 Summary and Conclusion

In recent decades, numerous developing countries, most notably China, experienced a strong economic growth, requiring more and more mineral and energy resources. As a consequence, industrialized countries are increasingly struggling to ensure the security of their energy and resource requirements, leading in the U. S. to a strong support for domestically produced bio-fuels. Yet, more than 30 years after the OPEC oil embargo in 1973, energy supply security still remains a diffuse concept. This paper has conceived a statistical risk indicator that includes four major aspects of long-term supply security: (1) diversification of sources in energy supply, (2) diversification of fuel imports, (3) long-term political and economic stability of export countries, and (4) a country's own contribution to the domestic energy supply.

Applying the proposed concept to empirical energy data on Germany and the U. S. (1980-2004), we basically find that there is a large gap in the energy supply risk between both countries, with Germany suffering much more from the tensed energy supply situation today than the U. S. This gap is likely to rise much further within the next decades: Given the nuclear phase-out decision of 2000, which demands the end of nuclear power in Germany at around 2022, and the foreseen dismantling of the notoriously uneconomic German hard coal production by 2018, the energy supply risk can be expected to rise even if the national goals of a 20% share of bio-fuels and a 30% share of electricity production from renewable energies will be reached in 2020. A major reason is that, based on the present share of about 14%, the required increase in "green" electricity production is much lower than the contribution of nuclear power, which currently amounts to almost 30%.

Appendix A: Proofs

Proposition I: The fuel-specific supply risk given by

$$\text{risk}_i = \sum_{j=1}^{J} x_{ij}^2 r_j,$$

is normalized: $0 \leq \text{risk}_i \leq 1$.

Proof of Proposition I: The fuel-specific risk$_i$ is non-negative because it is a sum of non-negative risk elements r_i multiplied by squared, and thus also non-negative, weights x_{ij}. That risk$_i$ is lower or equal than unity follows from $r_j \leq 1$, $x_{ij}^2 \leq x_{ij}$ for $0 \leq x_{ij} \leq 1$, $0 \leq x_{id}$, and restriction (1):

$$\sum_{j=1}^{J} x_{ij}^2 r_j \leq \sum_{j=1}^{J} x_{ij}^2 \leq \sum_{j=1}^{J} x_{ij} \leq \sum_{j=1}^{J} x_{ij} + x_{id} = 1.$$

Proposition II: The total supply risk, risk $= \mathbf{w}^T \cdot \mathbf{\Pi} \cdot \mathbf{w}$, is normalized:

$$0 \leq \text{risk} \leq 1,$$

where $\mathbf{w}^T := (w_1, ..., w_i, ..., w_I)$ and $w_1 + ... + w_I = 1$. $\mathbf{\Pi}$'s diagonal elements π_{ii} equal the fuel-specific risks, $\pi_{ii} = \text{risk}_i = \sum_j x_{ij}^2 r_j$, while the off-diagonal elements are given by $\pi_{kl} = \sum_j^J x_{kj} x_{lj} r_j, k \neq l$.

Proof of Proposition II: Similar to the fuel-specific risk, $\pi_{ii} = \text{risk}_i$, it is first shown that $0 \leq \pi_{kl} \leq 1$ for $k \neq l$: As a sum of products of exclusively non-negative factors, it is evident that π_{kl} is non-negative. Furthermore, π_{kl} does not exceed unity, as $r_j \leq 1$, $0 \leq x_{kd}$, and $0 \leq x_{lj} \leq 1$:

$$\pi_{kl} = \sum_{j}^{J} x_{kj} x_{lj} r_j \leq \sum_{j}^{J} x_{kj} x_{lj} \leq \sum_{j}^{J} x_{kj} \leq \sum_{j}^{J} x_{kj} + x_{kd} = 1.$$

Second, based on $0 \leq \pi_{kl} \leq 1$ for all $k, l = 1, ..., I$, it follows from $w_1 + ... + w_I = 1$ that

$$\text{risk} = \mathbf{w}^T \cdot \mathbf{\Pi} \cdot \mathbf{w} = \sum_{k=1}^{I} \sum_{l=1}^{I} w_k \cdot \pi_{kl} \cdot w_l \leq \sum_{k=1}^{I} \sum_{l=1}^{I} w_k \cdot w_l = (\sum_{k=1}^{I} w_k) \cdot (\sum_{l=1}^{I} w_l) = 1.$$

Appendix B: Tables

Table B1: Normalized OECD Risk Indicators.

Country	Risk	Country	Risk
Algeria	3/7	Netherlands	0
Angola	6/7	Nigeria	6/7
Canada	0	Norway	0
China	2/7	Poland	2/7
Colombia	4/7	Russia	3/7
Ecuador	1	Saudi-Arabia	2/7
Germany	0	South Africa	3/7
Iran	6/7	U.S.	0
Iraq	1	United Arab Emirates	2/7
Kuwait	2/7	United Kingdom	0
Libya	1	Venezuela	6/7
Mexico	2/7	Others	1

Source: OECD (2008).

Table B2: Crude Oil Supply Shares in % in Germany.

Origin	1980	1990	2000	2004
Algeria	5.2	3.8	6.1	2.5
Germany	3.8	4.0	3.0	3.0
Iraq	2.8	0.2	0.2	0.0
Iran	4.8	3.1	0.8	0.4
Libya	12.2	12.5	11.1	11.3
Nigeria	8.8	6.7	1.9	0.8
Norway	2.4	7.2	17.5	19.2
Russia	18.7	23.2	32.0	40.7
Saudi-Arabia	19.8	6.5	4.3	3.7
United Emirates	5.1	0.8	0.0	0.0
United Kingdom	11.8	16.2	12.2	11.4
Venezuela	1.3	5.0	1.8	0.7
Others	3.3	10.8	9.1	6.3
OPEC	60.8	39.3	26.7	19.4

Note: Calculations are based on IEA (2004a, 2006a).

Table B3: Crude Oil Supply Shares in % in the U. S.

Origin	1980	1990	2000	2004
Algeria	3.1	0.4	0.0	1.2
Angola	0.0	1.8	2.1	2.0
Canada	1.5	4.8	8.9	10.2
Ecuador	0.1	0.4	0.8	1.5
Iraq	0.3	3.8	4.2	4.1
Kuwait	0.2	0.6	1.7	1.5
Mexico	3.8	5.4	8.7	10.1
Nigeria	6.0	5.7	6.1	6.8
Saudi-Arabia	9.1	9.0	10.1	9.3
United Kingdom	1.3	1.5	1.8	1.5
U. S.	59.8	53.6	37.3	33.2
Venezuela	1.4	5.5	9.9	10.5
Others	13.4	7.5	8.4	8.1
OPEC	29.2	26.4	32.3	33.8

Note: Calculations are based on IEA (2004a, 2006a).

Table B4: Natural Gas Supply Shares in % in Germany and the U. S.

Origin	1980	1990	2000	2004
		U. S.		
Canada	3.9	7.5	15.5	16.4
U. S.	95.2	92.1	83.4	80.7
Others	0.9	0.4	1.0	3.0
		Germany		
Germany	32.2	25.8	22.5	18.6
Netherlands	33.6	26.8	19.3	20.3
Norway	12.2	11.1	18.8	22.7
Russia	21.9	35.7	35.4	35.3
Others	0.1	0.6	4.0	3.1

Note: Calculations are based on IEA (2004b, 2006b).

Table B5: Hard Coal Supply Shares in % in Germany and the U. S.

Origin	1980	1990	2000	2004
		U. S.		
Colombia	0.0	0.2	0.8	1.6
U. S.	99.8	99.7	98.7	97.3
Others	0.2	0.2	0.5	1.0
		Germany		
Australia	0.5	1.3	5.7	5.8
China	0.2	0.0	0.1	2.7
Colombia	0.0	0.1	4.2	5.4
Germany	85.4	84.9	57.2	42.4
Poland	1.7	3.0	10.4	10.9
Russia	0.2	0.4	1.4	8.5
South Africa	1.3	5.0	7.0	13.5
U. S.	2.0	0.8	1.1	1.4
Others	8.7	4.5	12.9	9.4

Note: Calculations are based on IEA (2004c, 2006c).

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