

# Indicators of energy security in industrialized countries

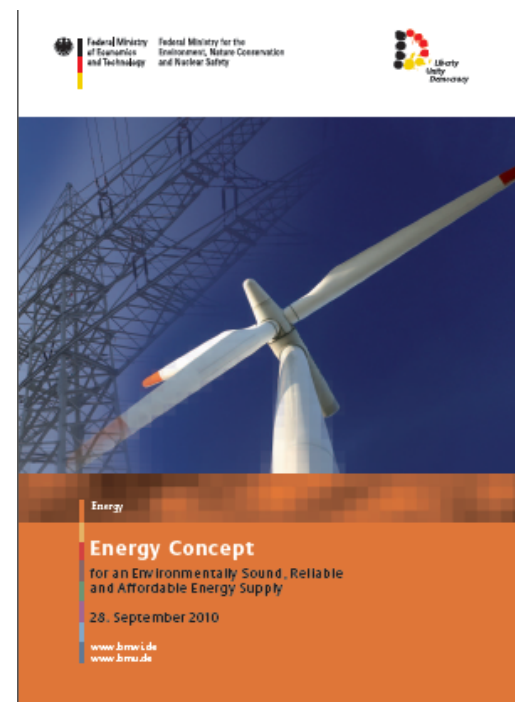
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Economic Challenges for Energy  
Workshop, Madrid, 30-31 January 2012

# Indicators for Energy Policy Objectives

- Energy Concept of German Government:
  - *“Securing a **reliable, economically viable and environmentally sound energy supply** is one of the great challenges of the 21st century. [...]*
  - *The German government will use **science based monitoring** to determine whether actual progress is as expected and to what extent additional actions needs to be taken.”*



# Phase-out of Nuclear Energy

- 2002 Act on Phase-Out of Nuclear Energy until 2022 → in force until Autumn 2010
- 2010 Act on keeping Nuclear Plants operating until 2038
- **FUKUSHIMA** → Return to Phase-out of Nuclear Energy (Act by 31<sup>st</sup> July 2011)  
→ 8 older Reactors off the Grid in 2011

# Energy Transition: Important Pillars

## Expansion of Renewable Energies

→ 35% of Gross Electricity

Consumption in 2020 (today 17%)

- **20% on Primary Energy Consumption** in 2020 compared to 1990

**Climate targets** unaffected: -40% greenhouse gas emissions in 2020 (compared to 1990)

# Overview Main Studies: all Modelling

## Target Scenarios (Zielszenarien):

- **PIK & IIRM (June 2011)** for Friedrich Ebert Foundation,  
27th June 2011
- **Energieszenarien 2011 by EWI, GWS, Prognos AG**  
for BMWi, July 2011

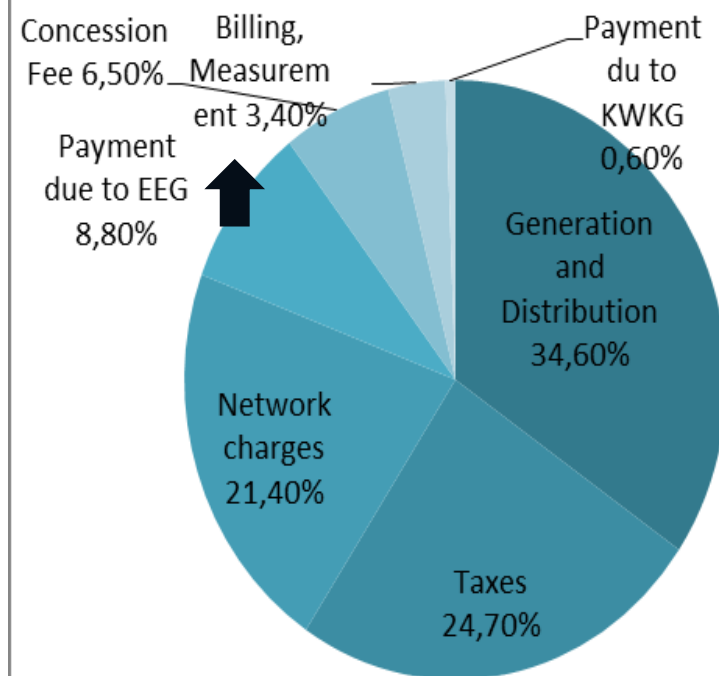
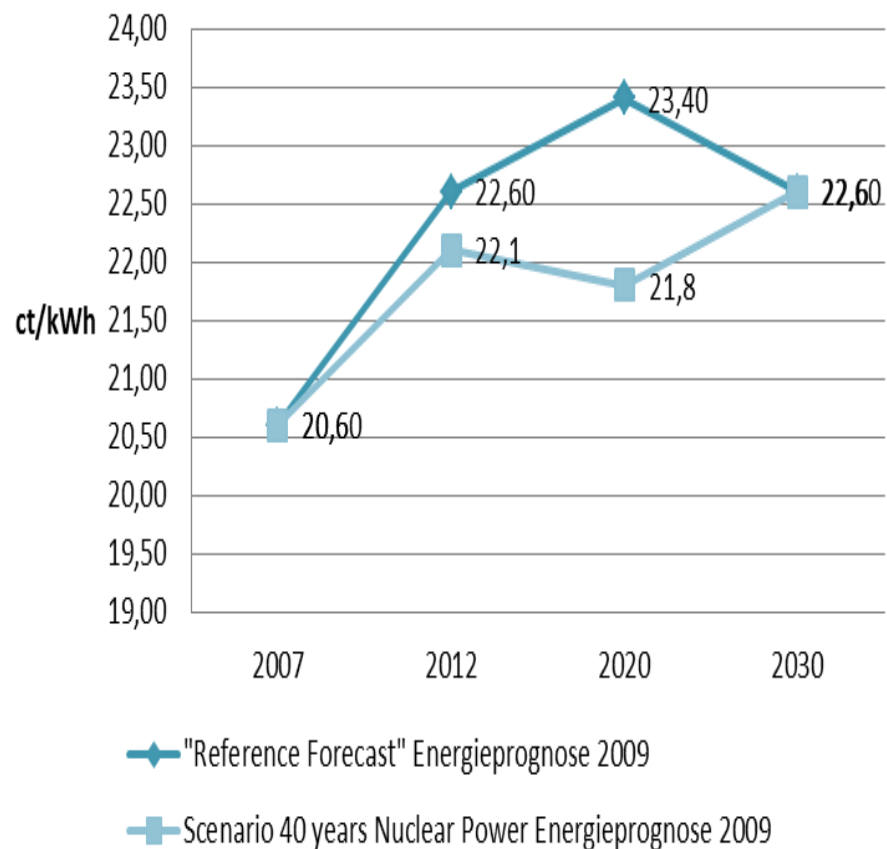
## NO target scenario:

- **Energieprognose 2009 by IER, RWI, ZEW** for BMWi,  
March 2010

## Other:

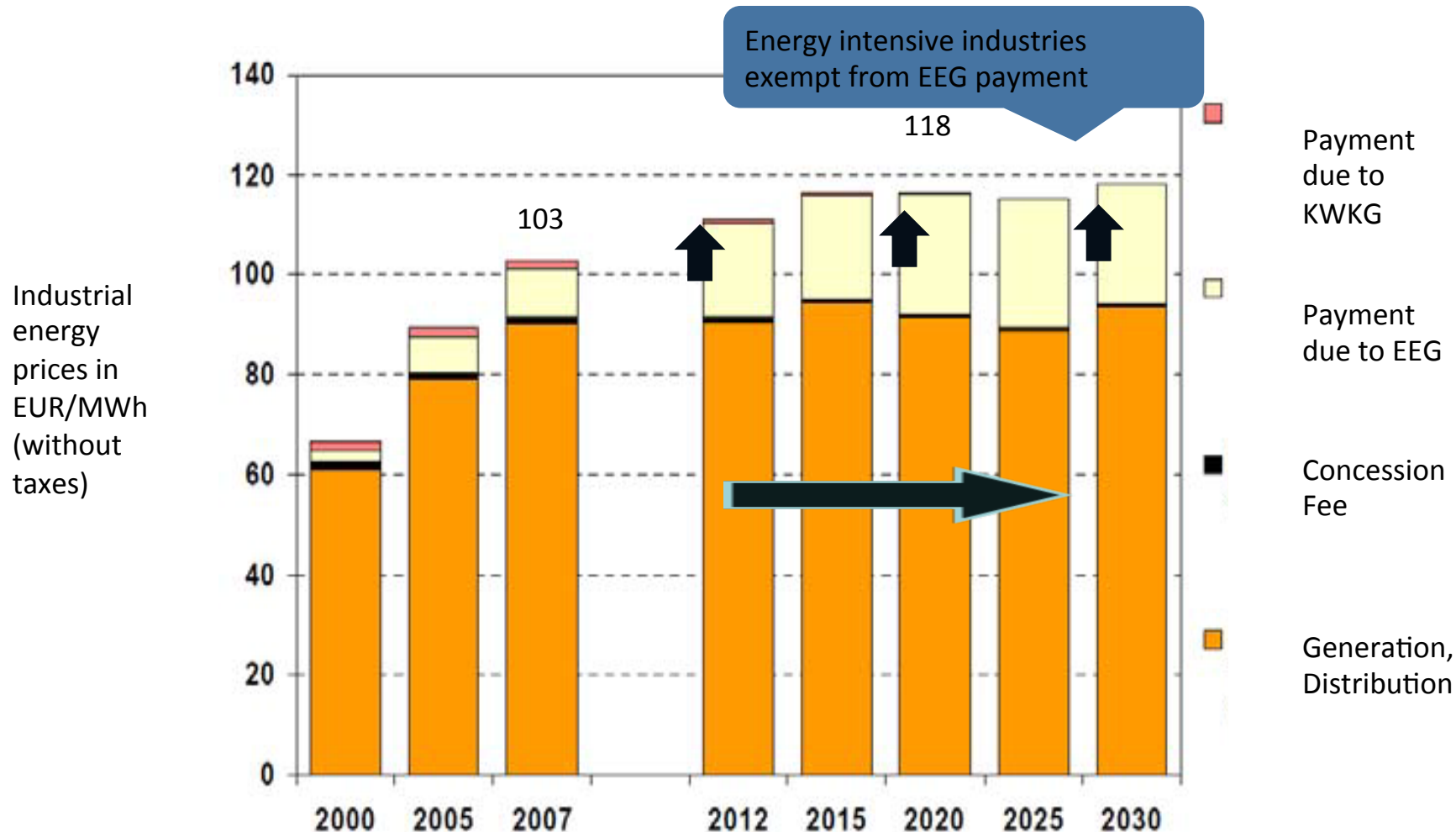
- **Leitstudie 2010 (Lead Study 2010)** for BMU, Dec 2010

# Expected Trends in Electricity Prices for HH



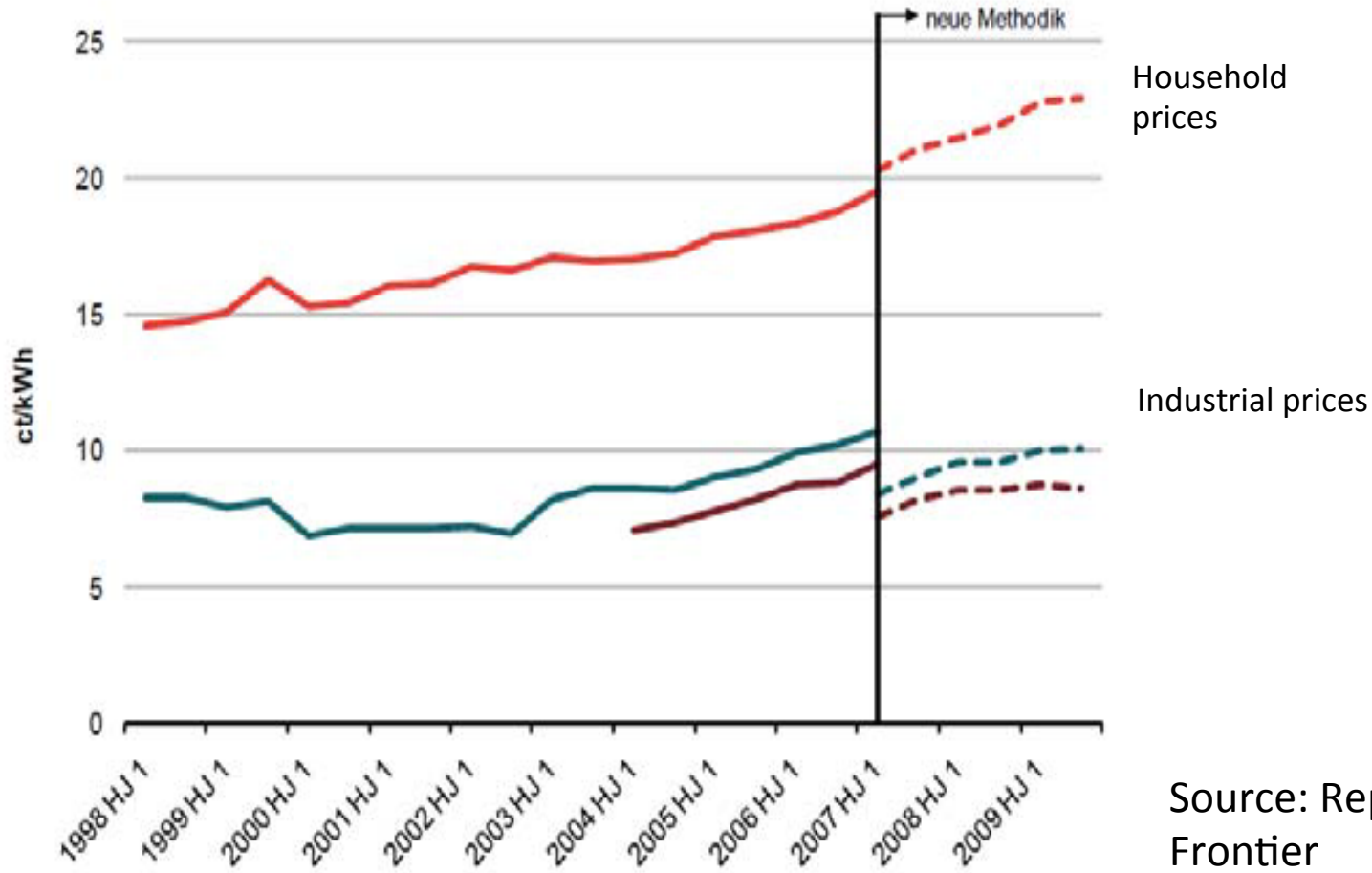
Shares of Electricity Prices for Households,  
quantity-weighted average, 1st April 2010,  
Source: BNetzA 2010

# Expected Trends in Electricity Prices for Ind



Source: Energieprognose  
2009, Reference Forecast

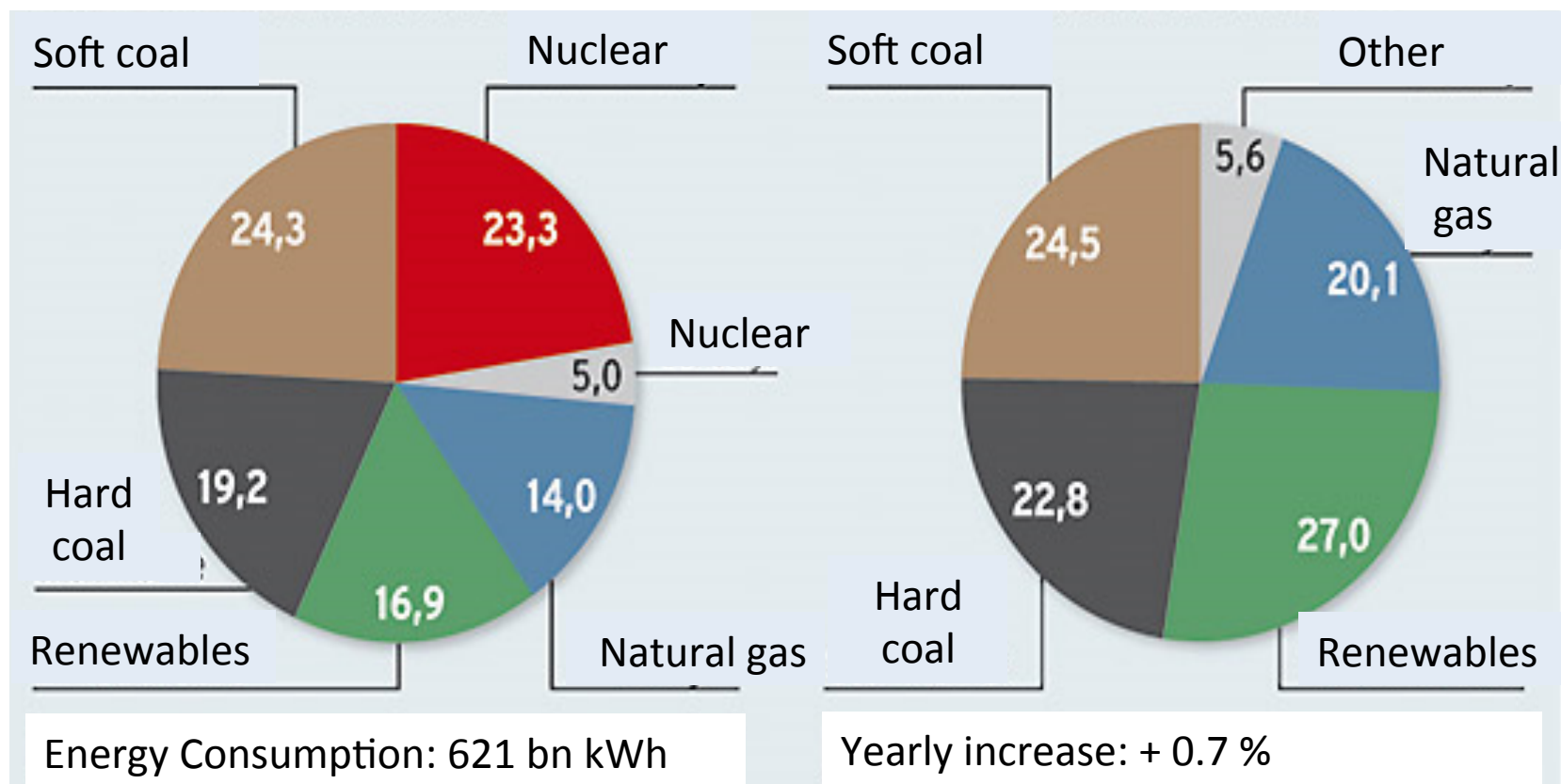
# Development of Electricity Prices



Source: Report  
Frontier  
Economics and  
ewi 2010,  
based on



# Structure of Electricity Generation



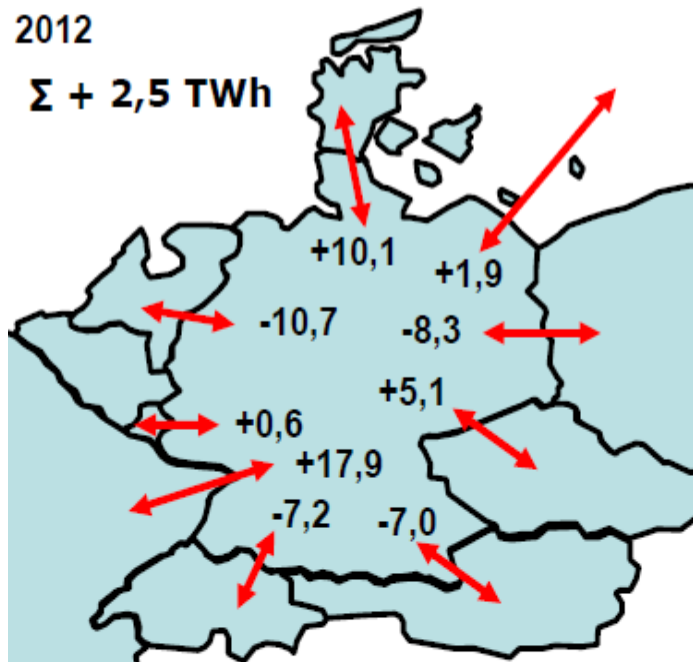
Quelle: Energieprognose 2009, F.A.Z.

# Electricity Imports

- **Energieprognose 2009** (28 TWh equals 3 % of electricity demand)

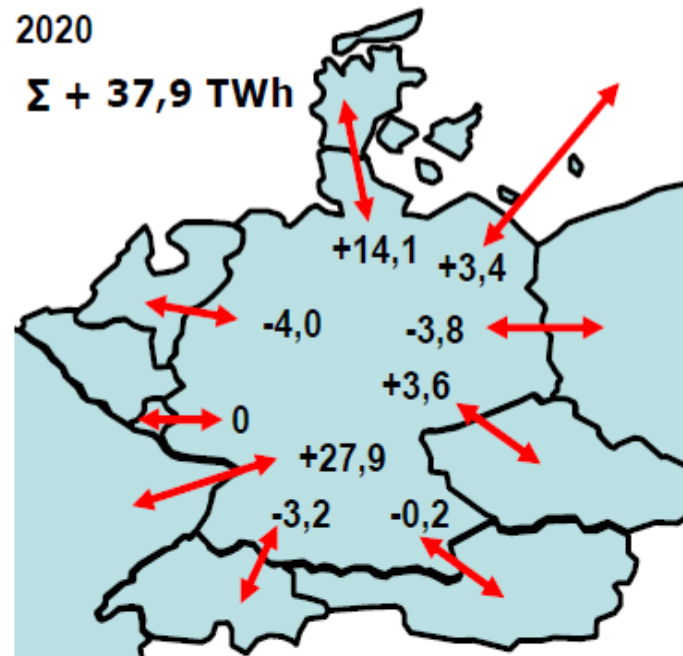
2012

$\Sigma + 2,5$  TWh



2020

$\Sigma + 37,9$  TWh



↔ Stromaustausch [TWh]  
(positiver Wert = Nettoimport; negativer Wert = Nettoexport)

Quelle: IER

Source: Energieprognose 2009

# Why Indicators?

- To observe the achievement of energy policy objectives and developments which are relevant for energy policy
- To warn about possible undesirable developments
- To benchmark (temporally and internationally)
- To raise awareness to the challenges & success of the transformation of the energy system

# What makes a good indicator?

- Strong reference to one of the three energy target criteria (economic, environment, security)
- Good data availability
- High transparency
- Comprehensibility

# Development of Indicators

From the objective to the indicator:

- Differentiate target dimensions  
→ *all three objectives are multidimensional*
- Analyze suitable indicators  
→ *indicator can be related to several objectives*
- Cover objectives/sub-objectives through indicators  
→ *in accordance with data quality  
& information content*

# Energy Security

Starting point:

Much has been said and written about the causes of energy insecurity, yet few efforts have attempted to quantify it.

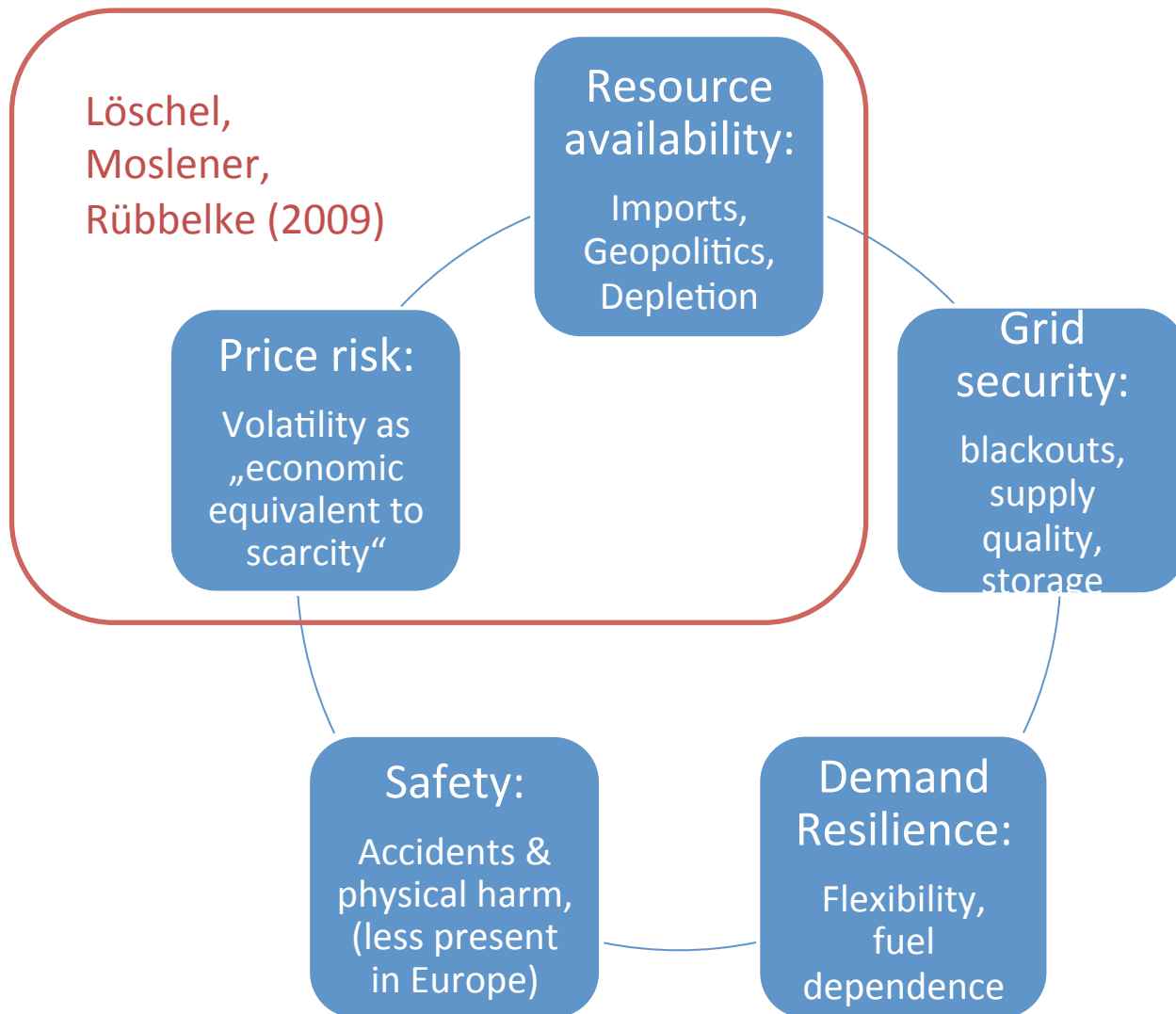
*“One difficulty, notably, rests in the dual nature of energy insecurity, characterised by both price and physical availability components”.*

(IEA (2007: 43))

# Different Approaches

- IEA indicators gather a **price component** (based on supplier concentration) as well as a **physical availability component** (based on energy carrier concentration) of energy security.
- **Diversity:** *“In the face of uncertainty and ignorance, an important insight to have emerged from a number of sciences is that **diversity** provides resilience to systems exposed to such incertitude”* (Grubb/Butler/Twomey (2006))
  - ➔ e.g., Stirling (1998), Awerbuch (2006).
- **Import dependence** ➔ e.g. Turton/Barreto (2006)

# Dimensions of Security of Supply





# Resource Availability

Germany is dependent on imports of energy carriers. Quantifying the risks evolving from that necessitates answering some questions.

- How **big** is **dependency**? *Share imported energy*
- Dependent on **few or many exporters**?  
*Herfindahl-Hirschman Index (HHI) of imports*
- How **reliable** are Germany's **trade partners**?  
*Weighting the exporters with Country Risks*
- How **dependent** are the **exporters** on Germany?  
*Confront import dependency with export dependency (possible new indicator)*

# Grid Stability

- Mainly relevant for electricity and gas
- **Ex post** orientated indicators
  - Measure blackouts (SAIDI)
  - Measure quality of supply (power quality)  
*Fluctuation of Voltage in electricity grids*
- **Ex ante** oriented indicators
  - Capacity of electricity, gas storages
  - Investment in grid

## SAIDI (Versorgungsstörungen im Elektrizitätsnetz)

Der „System Average Interruption Duration Index“ (SAIDI) ist ein Indikator für die Zuverlässigkeit der Stromversorgung. Er ist definiert als die durchschnittliche Versorgungsunterbrechung in Minuten pro Jahr und Kunden. Die Bundesnetzagentur berücksichtigt nur ungeplante Versorgungsstörungen, die länger als drei Minuten angehalten haben. Störungen aufgrund von „Höherer Gewalt“ werden nicht berücksichtigt (Bundesnetzagentur 2010: Monitoringbericht 2010).

Quelle	Jährliche Pressemitteilungen der Bundesnetzagentur und Monitoringberichte der Bundesnetzagentur.
Datengrundlage	Berichte der Netzbetreiber an die Bundesnetzagentur gemäß § 52 EnWG.
Zeitliche Abdeckung	Jährlich, ab 2006.
Regionale Abdeckung	Deutschland. Internationale Vergleichsdaten, für verschiedene europäische Länder sowie die USA liegen beim Council of European Energy Regulators (CEER) vor.
Nutzung	Bundesnetzagentur (2011): Monitoringbericht 2011. Monitoringbericht gemäß § 63 Abs. 43 EnWG i.V.m. § 35 EnWG.

Anmerkungen:  
In der Berechnung bleiben „Exceptional events“ die durch „Höhere Gewalt“ verursacht wurden, unberücksichtigt. Damit sollen die Zahlen um Auswirkungen dieser besonderen Ereignisse zu korrigiert werden. Gleichzeitig ist für die Betroffenen die Ursache einer Störung nicht relevant. Es ist zu diskutieren, welcher Zahl der Vorzug gegeben werden soll.

Der SAIDI wird von der Bundesnetzagentur auch für die Gasversorgung berechnet. Allerdings ist Erdgas besser speicherbar. Daher sind Versorgungsunterbrechungen weniger kritisch.

Zielbezug	Verfügbarkeit	Transparenz	Verständlichkeit
Gut	Gut	Gut	Mittel

## Example:

***SAIDI: average interruption of supply in minutes per customer***

***Good indicator for network energy carriers***

***Data verified by Bundesnetzagentur (German Grid Regulator)***

***Not directly known***

***Weakness: short interruptions and interruptions by Acts of God not taken into account***

# Demand Resilience

- Energy Transition will **increase the role of renewables** in relative and absolute terms
- Up to now: Mainly supply side reacts to stabilize the grid
- In the future: More important to **set incentives for demand side** to be flexible
- **New indicator(s) needed**
  - *Share of load which can be switched off*
  - *Share of demand at the stock exchange which is price sensitive*

# Security Indicators in Ind. Countries

Löschel/Moslener/Rübelke focus on resource availability and price risks

LMR distinguish between two sets of indicators:

Ex-post: indicators that describe current and past levels of energy security.

Ex-ante: indicators that reflect future risks of energy supply disruptions.

# What is Energy Security?

LMR analysis is subject to the following definition of energy security:

**Security of energy supply** is prevailing if at least current volumes of energy are available in the short- and medium-term at prices, which are not significantly exceeding the past medium-term-price-trend levels.

- ➔ The energy system exerts no serious negative impacts on the whole economic system.

# Two Crucial Components

This definition gathers two components which are crucial for the security of energy supply:

1. volume of energy supply,
2. energy price levels and their volatility.

Both components may be negatively affected by supply disruptions.

# Ex-Post Indicators

Referring to these components we can develop ex-post indicators

➔ that measure to which extent energy security prevails currently or prevailed in the past (after the market “fixed” the price).

The ex-post energy security indicator

$ES_{post} = ES_p * ES_v$  consists of two components:

- price component  $ES_p$  and
- volume component  $ES_v$ .



# The Price Component

If we want to get a picture of the current state, the current fuel price  $p_c$  has to be compared to the past medium-term-price-trend level  $p_{tr}$ .

The price component  $ES_p$  can be expressed:

$$ES_p = \begin{cases} \frac{p_{tr}}{p_c} & \text{if } p_{tr} < p_c \\ 1 & \text{if } p_{tr} \geq p_c \end{cases}$$

# The Volume Component

We have to check whether past (recent medium-term mean-values) energy volumes are available today.

$ES_V$  can be expressed:

$$ES_V = \begin{cases} \frac{v_c}{v_m} & \text{if } v_m > v_c \\ 1 & \text{if } v_m \leq v_c \end{cases}$$

# Relevance / Intent of Volume Component

The volume indicator is important for fuels whose prices are subject to indexed contracts as it is the case with natural gas in many countries.

The considered volumes reflect energy transport and production capacities, which of course, can be influenced by foreign supplier countries for strategic reasons.

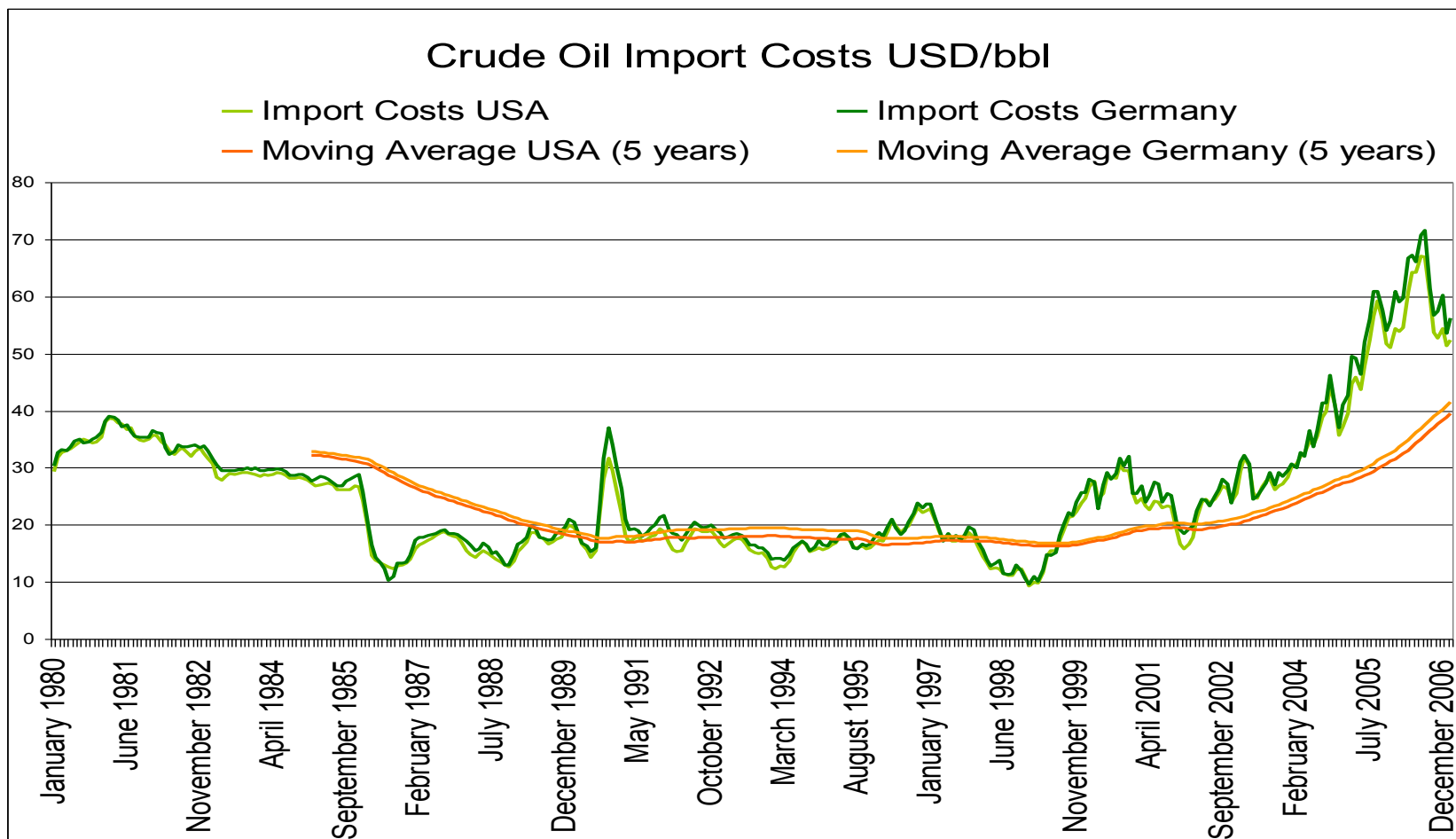
# Measured Values of the Indicator

If full energy security prevails, i.e.  $v_m \leq v_c$  and  $p_{tr} \geq p_c$ , the ex-post energy-security indicator  $ES_{post}$  becomes equal to unity. Otherwise, the indicator lies between unity and zero. It is the lower the less energy secure the current state is.

Furthermore, we may distinguish between strong energy security (the indicator is equal to unity in each subsector (coal, gas, oil, biomass etc.)) and weak ex-post energy security (indicator indicates full energy security for the whole energy sector as an aggregate).

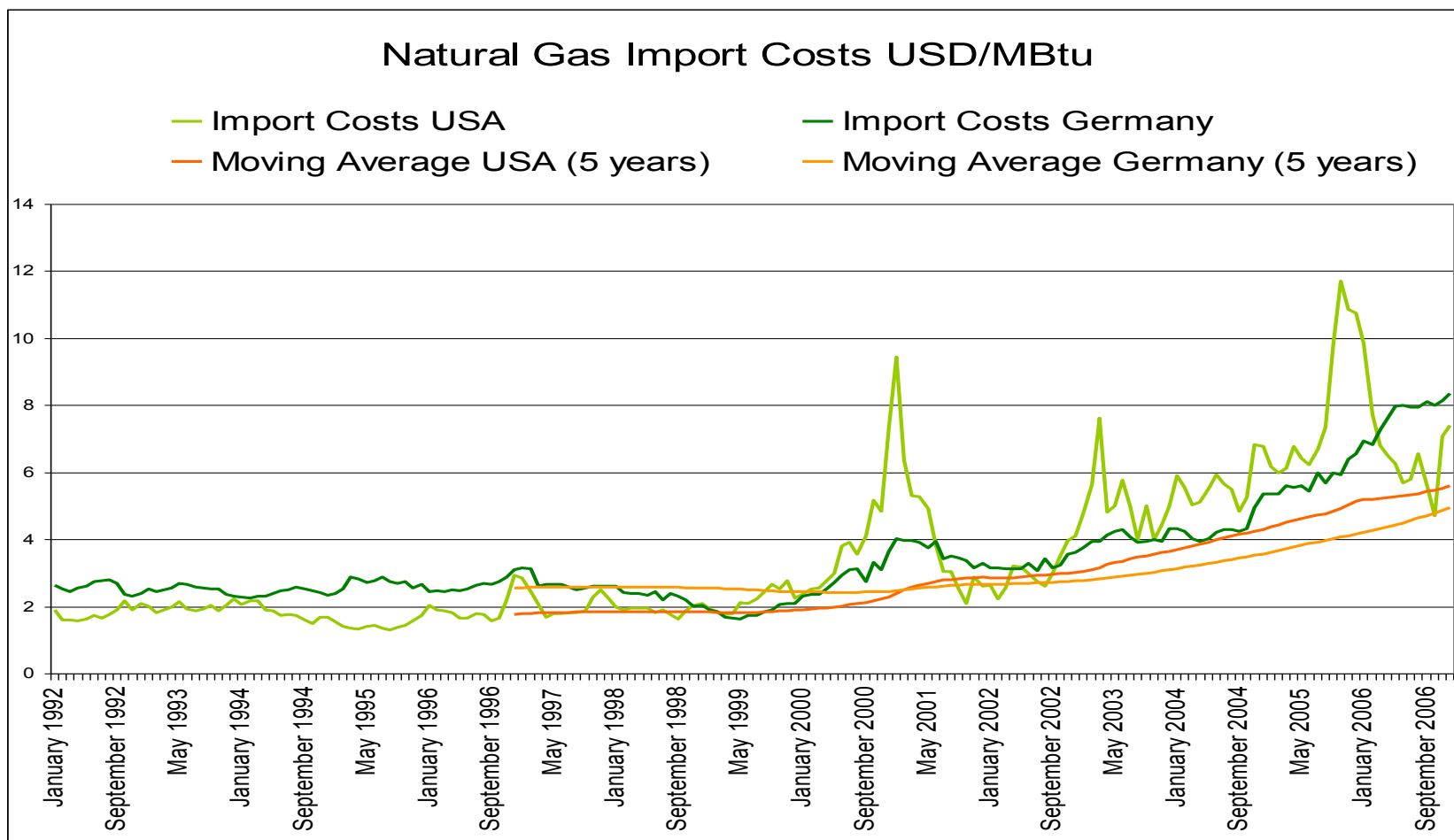
# Energy Market Movements

## Crude Oil Market



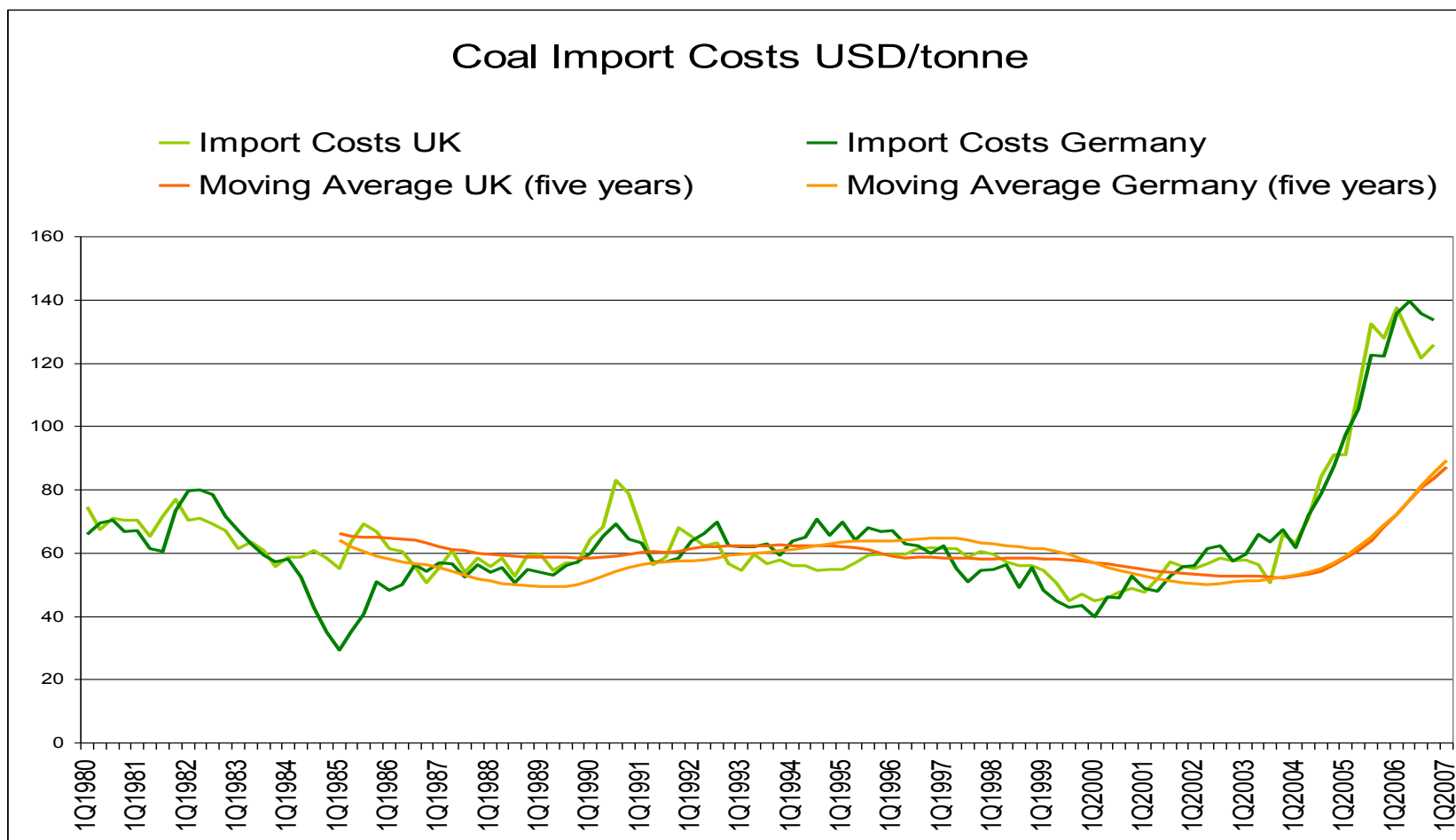
# Energy Market Movements

## Natural Gas Market

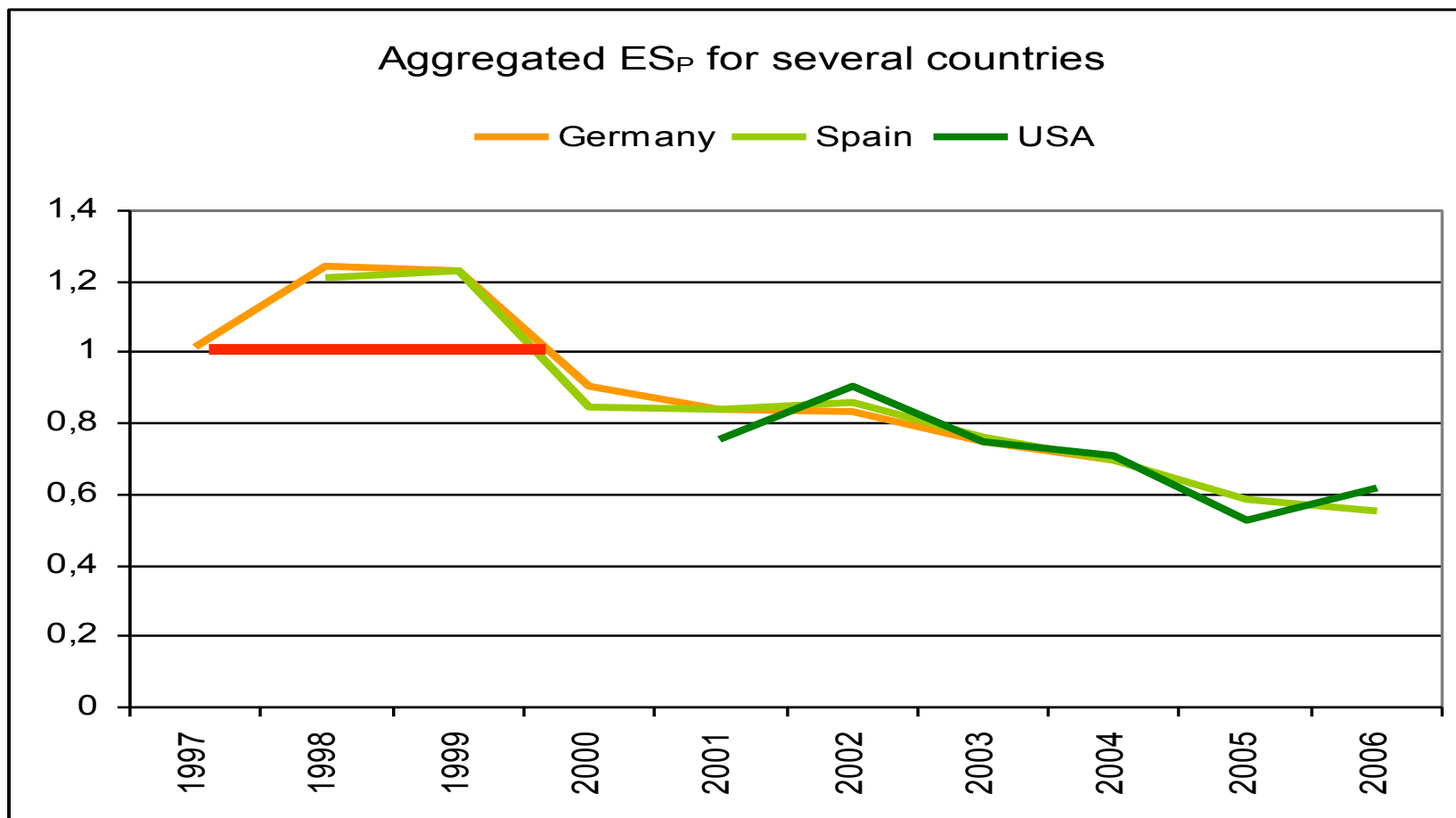


# Energy Market Movements

## Coal Market

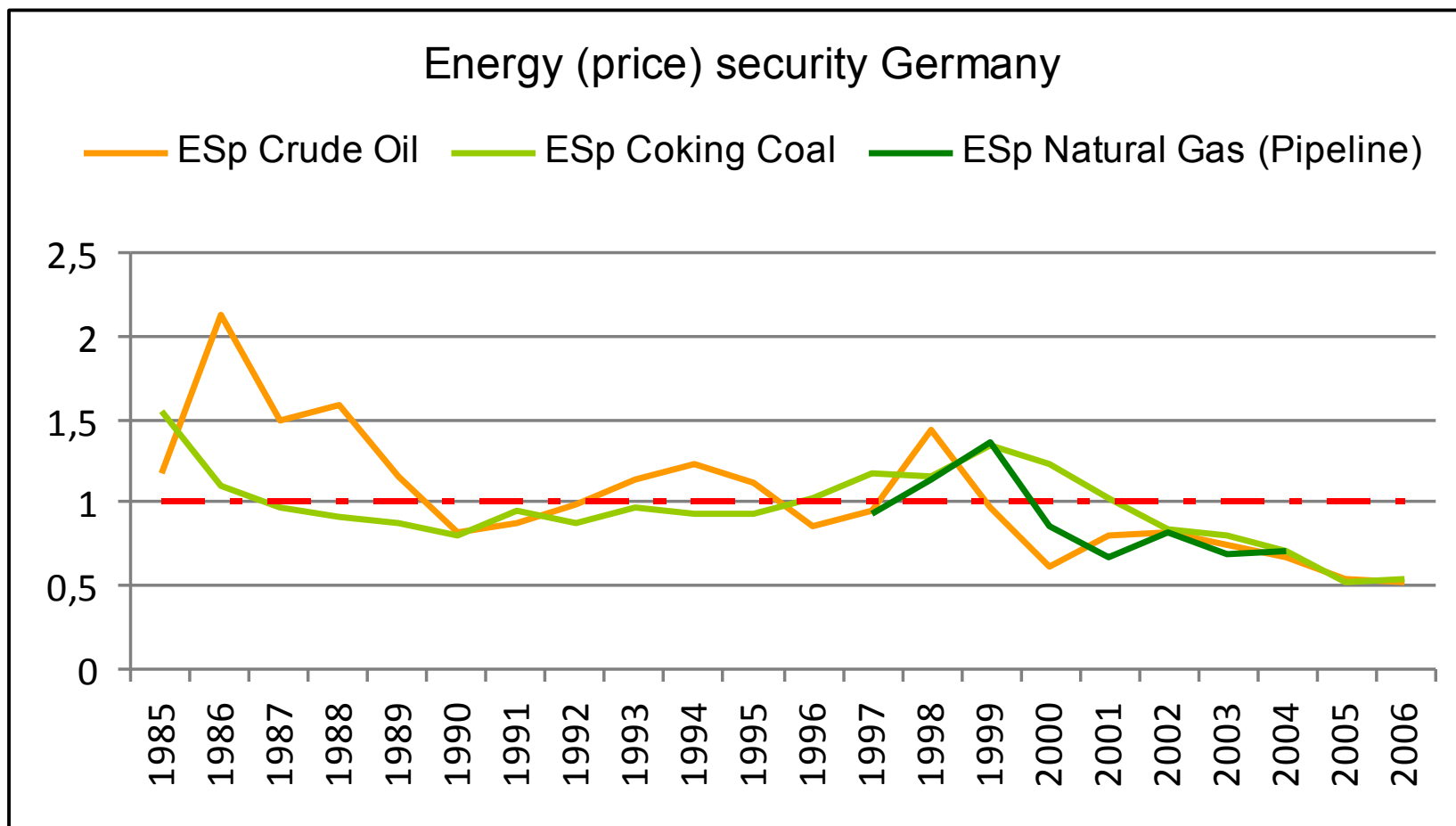


# Aggregated Indicator-Values for Crude Oil, Natural Gas and Coal





# Detailed Application to Germany



# Energy Policy and Supply Disruptions

Ex-post indicators can help both to evaluate the development of energy security in the past and to draw conclusions for the future respectively.

Nevertheless, they should be complemented by indicators which forecast future risks of supply disruptions in order to improve their merit for politicians which decide on measures preserving energy security.

Consequently, we have to design ex-ante indicators in addition.

# Time Dimensions of Political Responses to Disturbances of Energy Security

time dimension of response	sources of supply disruption	kinds of disruption
short-term	technical deteriorations; extreme weather events; terrorism and military and technological conflict; political tensions; strikes and disruptions blockades; earthquakes	strategic/political
medium-term	transport infrastructure, power plants etc. have to be replaced (depreciation); local/ regional energy sources run out of stocks	technological and source-limitation disruptions
long-term	global energy-resource stocks vanish	source-limitation disruptions

# Further Dimensions

The time dimension of energy security can be related to a **geographical dimension**: there may be a temporary shortage of supply in one region (e.g. due to a leak in a gas pipeline) while the global supply is not endangered.

Not only time and geographical dimensions play an important role but also the **specific energy resource** is of relevance. There may be no shortage in one energy carrier (e.g. natural gas), while there arises a shortage in another (e.g. crude oil).

# Indicators with Different Dimensions

The ex-ante indicator should take the different dimensions into account.

Diversity of

- consumed energy carriers,
- employed fuel transport technologies/  
channels and
- energy suppliers

can contribute to a higher level of energy security.

# Ex-Ante Indicators

If disruptions appear surprisingly, then available policies to address these disruptions are ex-post corrective measures. Of course, it would be advantageous to prevent disruptions instead of just mitigating the consequences.

In order to prevent surprises regarding disruptions, indicators reflecting the risk of and signalling future disruptions are crucial. If disruptions can be foreseen, then ex-ante measures may effectively prevent those disruptions.

# Components of the Indicator

The indicator  $ES_{ante}$  includes two components, i.e. component  $ES_{CS}$  related to the concentration of suppliers as well as a component  $ES_{DF}$  associated with the diversity of fuels.

It therefore gathers the basic ideas incorporated in the IEA energy security indicators:

- 1) the mitigation of market concentrations and
  - 2) the increase in the diversity of fuels
- raise energy security.

# Balancing and Diversifying

Balancing between and diversifying the various sources of energy supply by product (DF diversity of fuel) and by geographical region (CS concentration of suppliers) (European Commission (2001)) in the ex-ante indicator:

$$ES_{ante} = ES_{CS} * ES_{DF}$$



# Concentration of Suppliers

The component  $ES_{CS}$  largely coincides with the  $ESMC_{pol}$  (IEA Energy Security Market Concentration):

$$ESMC_{pol} = \sum_i (r_i * S_{if}^2)$$

where  $S_{if}$  is the share of each supplier country  $i$  in the market of fossil fuel  $f$ . The **higher** the  $ESMC$  value, the higher the level of market concentration (HHI) and the **lower** the level of energy security.  $r_i$  represents the political risk rating of supplier country  $i$  (Hermes credit rating).

# Fuel Diversity

Component  $ES_{DF}$  reflects the diversity of fuels:

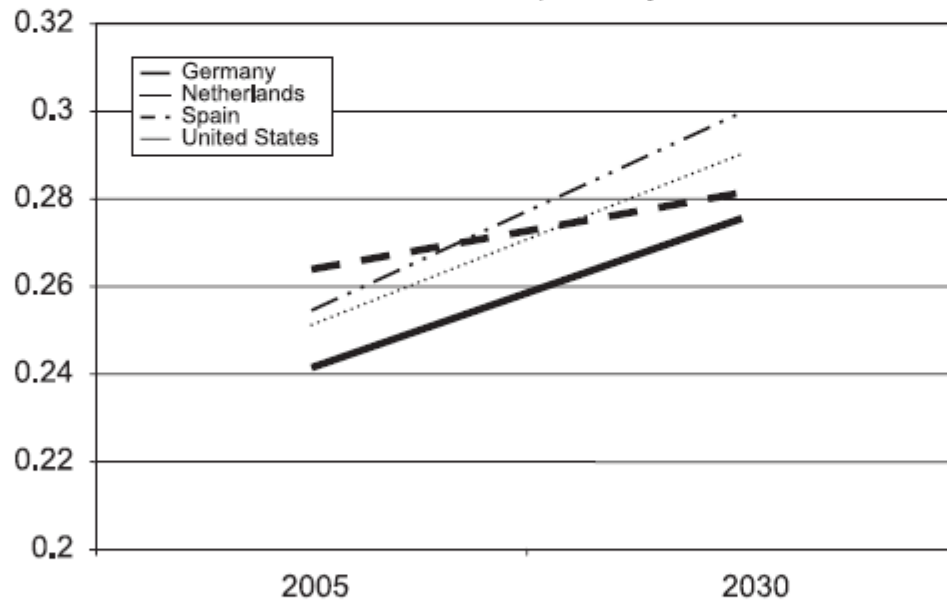
$$ES_{DF} = \sum_f (C_f / TPES)^2 ,$$

where  $C_f / TPES$  is fuel  $f$ 's share of country  $i$ 's fuel mix (total primary energy supply)

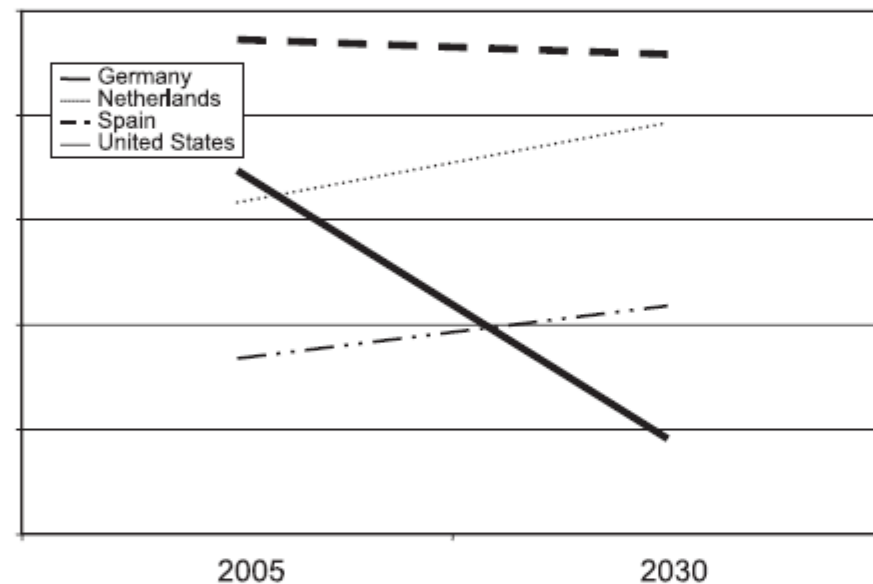
Given a high level of diversity, production and transportation disruptions in one single fuel subsector tend to have minor negative effects on the economy in the fuel consuming country.

# Ex ante Indicator

Ex ante indicator - politically unrated



Ex ante indicator - politically rated



# Summary and Outlook

- Security of energy supply is a vague concept.
- We suggest a definition for energy security which implies that security prevails, if major negative effects of the energy sector on the whole economic system do not arise.
- Ex-post indicators refer to observable developments concerning energy prices and volumes.
- Ex-ante indicators which signal risks of future supply disruptions are of major political relevance.

# Summary and Outlook

- Most indicator concepts are rather general and have to be elaborated in more detail.

- Resource availability:

Up to now: mostly import diversification measures, bilateral dependencies not taken into account

New development in progress: add the dependence on exports of the supplier country

- Not only prices and resources

# Other dimensions

- **Grid stability:**

Good indicator: SAIDI, still improvable  
(German Grid Regulator): possibly new  
indicator for *power quality* in the future

- **Resilience of the energy system (flexibility  
of electricity demand)**

Important parameter for the vulnerability of  
the economy → share of price-elastic bids at  
the spot market (only if transparency of the  
spot market bids is given)