Gulf Research Center Foundation
Knowledge for All

SEVENTH FRAMEWORK PROGRAMME

secure
Security of Energy Considering its Uncertainty, Risks and Economic implications

The Gulf and European Energy Supply Security

Background Papers

Conference on

**Energy Security:
Potential for EU-GCC Cooperation**

November 9-10, 2010
Manama, Bahrain

© Gulf Research Center Foundation 2010
All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior written permission of the Gulf Research Center Foundation.

Gulf Research Center Foundation
49, Avenue Blanc
1202 Geneva, Switzerland.
Tel.: +41 227162730, Fax: +41 227162739
Website: www.grcf.ch

The opinions expressed in this publication are those of the author(s) alone and do not state or reflect the opinions or position of the Gulf Research Center Foundation.

CONTENTS

Introduction

The SECURE Project

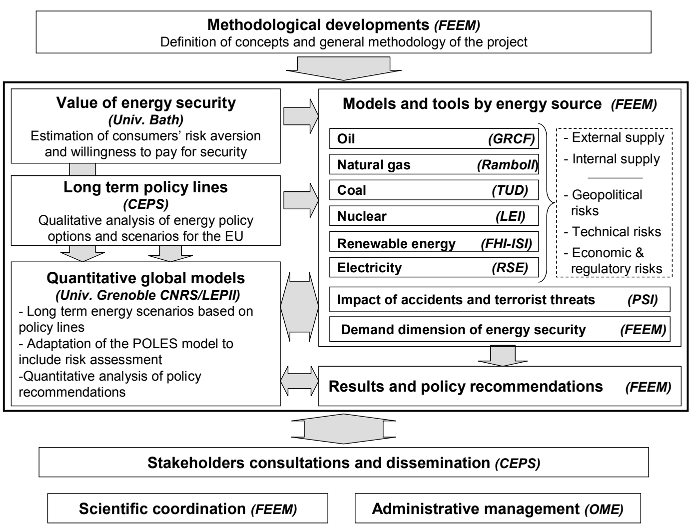
SECURE (Security of Energy Considering its Uncertainty, Risk and Economic Implications) is a research project funded by the European Commission under the Seventh Framework Program.

The project, which started in January 2008 and will finish by December 2010, is carried out by a consortium of 15 prestigious partners from 11 countries (see list on Page 8). The Observatoire Méditerranéen de l'Energie is the project coordinator, while the scientific coordinator is Fondazione Eni Enrico Mattei.

The ambition of the SECURE project has been to build a comprehensive framework that considers most of the issues related to security of supply, including geopolitics, price formation and the economic and technical design of energy markets inside and outside the EU.

The project develops tools, methods, and models to evaluate the vulnerability of the EU to the different risks which affect energy supplies, in order to help optimize the Union's energy insecurity mitigation strategies, including infrastructure investment, demand side management and dialogue with producing countries.

Structure of the SECURE project



All major energy sources and technologies (oil, natural gas, coal, nuclear, renewables and electricity) are addressed from upstream to downstream by means of both global and sectoral analysis of technical, economic/regulatory and geopolitical risks. The analysis is not limited to supply issues, but also integrates demand issues related to energy security.

The diagram 'Structure of the SECURE Project' illustrates the different modules of the SECURE project, their interactions, and the coordinating and responsible organization for each module.

The SECURE project has both strong quantitative and qualitative components and is designed not only to provide a comprehensive methodological and quantitative framework to measure energy security of supply, but also to propose relevant policy recommendations on how to improve energy security taking into account costs, benefits and risks of various policy choices

Consultation among stakeholders is an important element of the SECURE project. Several workshops have been organized both in Europe and in the main energy supplying regions for Europe (Russia, North Africa and the Gulf) in order to discuss and test draft project results.

The SECURE project will thus provide the European Commission, as well as EU governments and regulators, with a tool to support their decision-making process towards the definition of energy policies and strategies.

In particular, the results of the project will be useful to achieve the appropriate energy mix regarding energy security of supply and sustainability requirements; to improve the internal energy market regulatory framework; to develop stable relations with energy exporting countries and external partners; and to optimize the synergies between member states to improve security of supply.

Energy Security – Potential for EU-GCC Cooperation

The present book has been prepared as an ad-hoc background document for the "Conference on Energy Security – Potential for EU-GCC Cooperation" organized in cooperation with the Bahrain Center for Strategic, International and Energy Studies. It is a collection and summary of those SECURE project results which have a specific relevance for EU-GCC cooperation.

The first paper contains the highlights of the energy scenarios developed in the context of the project. Work for this paper was conducted primarily by LEPII-CNRS. This paper describes the set of world energy scenarios that have been developed under the SECURE research project in order to study the "Climate Policy and Energy Security Nexus" in a European perspective. It is based on the statement that it is impossible to examine the energy security issue without developing a full set of consistent hypotheses on the intensity of emission reduction policies in the different world regions. This is understandable as these policies, if they are sufficiently ambitious to have an impact on GHG emissions and on the climate, will also have a noticeable impact on the international energy markets. The paper examines the impacts of three main scenarios –- Muddling Through (low intensity climate policies), Europe Alone, and Global Regime -– on the world and European energy systems. The study confirms that the world energy future will be fully different in the two extreme cases and that the Global Regime helps to alleviate both the climate problem and the long-term sustainability problem of hydrocarbon production. The Europe Alone case does not solve the latter problem, but it makes Europe less vulnerable to the risks associated with future energy shocks.

The second and third papers, which are primarily the responsibility of GRCF, are devoted to the security of oil supplies – an item of intense common interest for EU-GCC cooperation. The second paper focuses in particular on threats to oil supply security. It follows an analytical approach, distinguishing different types of threats rather than bundling all together in an undifferentiated scare scenario. The primary distinction is between geopolitical and military threats: the former are linked to political developments and the adoption or reform of policies affecting oil production and exports (resource nationalism, political instability). The latter are linked to the use of military force or violence on the part of either state or non-state actors. A third section of the paper deals with potential threats to oil transportation on the high seas.

The paper argues that there is no easy and immediate connection between resource nationalism and/or political instability, and global supply of oil and gas. This is not because political developments are irrelevant for influencing oil and gas supplies, but because this influence is highly variable and unpredictable. Political instability and resource nationalism are shown to have rarely been associated with acute supply crises or shortfalls. Their effect is rather gradual and normally compensated by action in other parts of the system.

Concerning threats subsequent to the use of military force, the paper argues that oil and gas installations appear to be much more resilient to armed conflict than is normally acknowledged. Interstate wars are a low-probability event; they are generally confined to two main belligerents and contained. In contrast, civil wars or violent action on the part of non-state actors are phenomena whose frequency has not diminished at the global level. Cases in which violent action on the part of non-state actors has inflicted significant damage to existing installations include the "insurgency" phase in Iraq and the activities of MEND in Nigeria. If oil installations are in remote or inhabited locations, the cost-benefit balance of attacking oil installations is not very attractive for the non-state actor. However, it is very obvious that a government's inability to overcome or reabsorb violent opposition discourages international oil company investment even if the violence does not affect the vicinity of oil and gas installations.

Concerning threats to oil shipping, the paper argues that maritime logistics are unlikely to generate major crises, but require constant attention. Patrolling and surveillance of maritime traffic is essential, as is investment to reduce pressure on key choke points, such as the Strait of Hormuz. Investment to reduce traffic in enclosed seas is highly advisable.

The third paper deals with the functioning of global oil markets and its impact on energy security. It is argued that Energy security is primarily a function of investment. Investment in a market economy is a function of the expected revenue stream, which in turn is a function of prices. A well-functioning market is therefore a key component of security. In this approach, the main obstacle to oil and gas security of supply is the growing volatility of prices and their fundamental unpredictability.

Security itself is also dependent on prices, because customers feel secure if they can buy all the energy they need at prices that they can afford.

The paper offers a number of policy indications to contain volatility within limits that will not prevent the formation of a prevailing view of the likely evolution of prices in the medium and long term, which is the prerequisite for sufficient investment.

The fourth paper (whose primary responsibility has been with Ramboll with support from OME and GRCF) deals with security of gas supplies. Until recently, the Gulf has not been a main source of gas imports into Europe, but this situation is changing fast. Because the main dimension of European insecurity with respect to gas imports is the excessive dependence on a small number of historical suppliers, the emergence of an important new potential source of supplies, such as the Gulf and in particular Qatar, represents a boost to European security in itself. In addition, exports from the Gulf are in the form of LNG, which adds considerable flexibility to the management of the European gas grid, which has been plagued by insufficient interconnections. As LNG cargoes are easily redirected in case of some disturbance, all that is necessary is to make provision for sufficient regasification capacity distributed along the coasts of the European Union to acquire the possibility of serving all vulnerable customers in the event of an emergency.

The last paper, whose responsibility lies with the Fraunhofer Institute and the Vienna University of Technology (Energy Economics Group), is about the potential for renewable sources of energy. The paper is based on the European experience so far and details the potential for greater reliance on renewable sources but also the cost and problems connected with it. As the GCC countries have manifested rapidly growing interest for developing renewable energy sources, notably solar and wind, we believe that this is an area in which fruitful dialogue and cooperation is possible.

The appendix contains a list of proposed policy measures that the SECURE project offers to European politicians and decision makers for consideration with the objective of enhancing European energy security.

The issues of energy security and climate change are unfortunately frequently framed in an adversarial fashion – as if the objective is solely or primarily to reduce dependence on "their" oil. We believe that this approach is profoundly wrong. It is clear in our minds that the world will continue to need growing volumes of oil and gas for the foreseeable decades, in conjunction with the rapidly increasing demand in the major emerging countries. Greater reliance on coal is problematic because of the impact on global warming, and carbon capture and sequestration for coal fired power plants is not making the progress that had been hoped for.

As the CEO of Saudi Aramco, Khalid Al-Faleh, has said:

"We will have to meet the world's increased energy needs, and must do so in the most responsible manner. So how do we best address the challenge of ready access to affordable energy?

The short answer is that the world will continue to rely on traditional fossil fuels for most of its energy needs for the coming decades. In fact, these energy sources – namely coal, oil and natural gas – are expected to account for about four out of every five units of energy that mankind will consume for the foreseeable future. In addition, even though the share of fossil fuels in the energy mix may decline over the longer term, the absolute quantities of energy from these sources will continue to rise simply because total energy demand is set to expand so significantly. At the same time, alternative sources of energy should grow – and indeed must grow – in order to play their part in meeting that rising demand."

EU-GCC cooperation may play a very important role in fostering a climate of broader global cooperation that will provide the world with sufficient energy to achieve its development goals while at the same time preserving the health of our planet.

SECURE Project Partners: 15 Leading European Research Institutions

	Partner		Country
Coordinator	Observatoire Méditerranéen de l'Energie	OME	France
Scientific Coordinator	Fondazione Eni Enrico Mattei	FEEM	Italy
	Ramboll Oil & Gas	RAMBOLL	Denmark
	Lietuvos Energetikos Institutas	LEI	Lithuania
	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.	FHI-ISI	Germany
	Joint Research Centre	JRC	Belgium
	Technische Universität Dresden	TUD	Germany
	Paul Scherrer Institut	PSI	Switzerland
	Ricerca sul Sistema Energetico	RSE	Italy
	Energy Research Institute Russian Academy of Sciences	ERI RAS	Russian Federation
	The University of Bath	Bath	U.K.
	Gulf Research Center Foundation	GRCF	Switzerland
	Centre for European Policy Studies	CEPS	Belgium
	Vienna University of Technology, Energy Economics Group	TU-WIEN	Austria
	Centre National de la Recherche Scientifique – LEPII	CNRS	France

The European Energy Sector and the Climate-Security Nexus in the SECURE Scenarios*

Introduction

It is usually considered that the development of national or regional energy policies should be based on three pillars: energy security, environmental sustainability and economic competitiveness. This is particularly true for Europe, where each one of these pillars is brought forward by one dedicated institution, respectively the Directorates General for Energy and Transport, for Environment and for Competition. But this is also true for other countries or regions of the world, as the development of sound energy policies is often considered as based on trade-offs, aiming at the right balance between potentially conflicting goals. The key argument of this paper is to demonstrate that these targets may be put into convergence, according to the policy hypotheses retained at the global and regional level. In particular, the adoption and implementation of strong climate change and emission reduction policies may be considered as the most effective way to enhance energy security through a lower degree of dependence of the European energy system on fossil fuels.

In order to explore this "energy security and climate policy nexus," we use the POLES world energy model. In line with former energy foresight exercises performed at European and world level with this model, we describe a family of scenarios based on consistent sets of exogenous hypotheses on economic growth, energy resources, technology performances and climate policies. The POLES model is not a General Equilibrium Model, but a Partial Equilibrium Model aimed at describing the energy sector within a year by year dynamic recursive simulation framework. In this paper, we describe the results of four scenarios in order to illustrate the consequences of different settings concerning climate policies on the fundamentals of the energy markets, both at global and regional level.

These scenarios are currently developed and used in the European SECURE project, on top of the model's Business as Usual projection. The first one is called Muddling Through and illustrates the consequences of relatively low intensity and non-coordinated climate policies in the different world regions. This scenario can be used as a reference case, to which stronger policy cases can be compared. The second and third cases respectively identified as Muddling Through with Europe Plus, and Europe goes Alone, describe situations in which Europe implements gradually stronger climate policies than in the mere Muddling Through case, while the rest of the world sticks to low intensity climate policies. Finally, the Global Regime scenario illustrates the consequences of coordinated and ambitious climate policy, shared at world level.

The exercise shows that energy policies in the Muddling Through case result in a noticeable limitation of emissions compared to Business As Usual case. However, the global emission level reached in 2050 far exceeds the one that is considered as reasonable in IPCC's AR4. The Europe Alone scenario helps to show that in a world with low policy coordination there might still be strong advantages in pursuing an ambitious regional climate policy as it may considerably limit the vulnerability of Europe to events occurring in an otherwise very unstable energy world. The Global Regime case not only helps to constrain climate change in an acceptable range but also changes

This paper was written by Patrick Criqui and Silvana Mima of LEPII the whole picture of the world energy system in the first half of the century. In particular, the long term sustainability of the oil and gas production profile is significantly improved. Two variants are developed for this case: Global Regime with two carbon markets (GR-2M) and Global Regime with full trade for carbon (GR-FT) in order to test the consequences of a differentiated or a unified carbon emissions market.

Section 1 of this paper briefly presents the POLES model and the Muddling Through scenario, which, although it contains some elements of emission reduction, represents a state of the world that is maybe probable, but surely not desirable from the climate change perspective. Section 2 is dedicated to the presentation of the climate policy alternative scenarios and to the comparative analysis of their results in terms of emission performances and impacts on the world and European energy system to 2050. Section 3 discusses the consequences for the international energy markets and for the energy import profiles of Europe. The last section translates the conclusions of this study in terms of risks and vulnerability; it also points to the double dividend that may be associated with a change in the European energy paradigm.

1. The POLES Model and the Muddling Through Projection

The Muddling Through projection provides an image of the energy scene upto 2050, resulting from the continuation of ongoing trends and structural changes in the world economy, with only low intensity and non-coordinated climate policies in the different world regions.

Through the identification of the drivers and constraints in the energy system, the model used in this exercise allows the description of the pathways for energy development, fuel supply, greenhouse gas emissions, international and end-user prices, on a year by year basis from today to 2050. The approach combines a high degree of detail in the key components of the energy systems and a strong economic consistency, as all changes in these key components are largely determined by relative price changes at sectoral level. The model identifies 47 regions for the world, with 22 energy demand sectors and about 40 energy technologies – now including generic "high energy efficiency" end-use technologies. Therefore, each scenario can be described as the set of economically consistent transformations of the initial Business As Usual projection that is induced by the introduction of policy constraints.

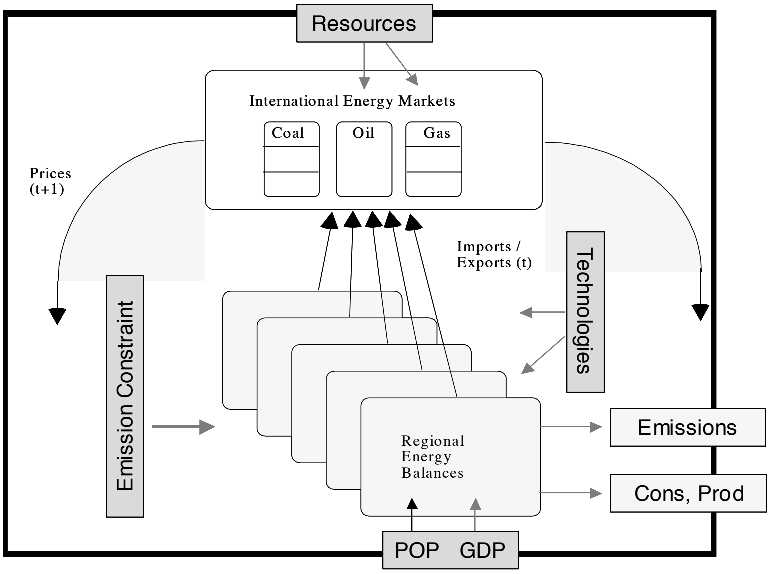
1.1. The POLES Model

The POLES model is a partial equilibrium model of the world's energy system that provides a detailed year-by-year projection until 2050 (or in some studies 2100), for the different regions of the world. The model simulates the energy demand for each economic sector, the supply and prices for the primary energy sources on the international markets, and the impacts of innovation, experience effects and R&D in new and renewable energy technologies and major energy conversion systems (electricity or hydrogen-based for the longer term).

The model therefore provides a consistent framework for studying the interconnected dynamics of energy development and environmental impacts. Projections are made on the basis of exogenous economic growth and demographic projections for each region. It takes into account the resource constraints for both oil and natural gas and enables the calculation of greenhouse gas emissions from the burning of fossil fuels and, further on, of the costs (marginal and total) of reducing emissions in the various countries or regions.

It thus makes possible the simulation of various emission constraint scenarios and the identification of the consequences of introducing a carbon tax or emission quotas systems. The main limitation of this modelling system is probably that it does not account for macro-economic feedbacks. However, this also allows the production of a relatively robust estimate of the impacts of climate policies on the sole energy sector, while the macro impacts are most often taken into account in joint studies with other energy economy models such as GEM-E3 (NTUA, Athens) or IMACLIM (CIRED, Paris).

Figure 1: The POLES Model Simulation Process



Source: POLES model-LEPII

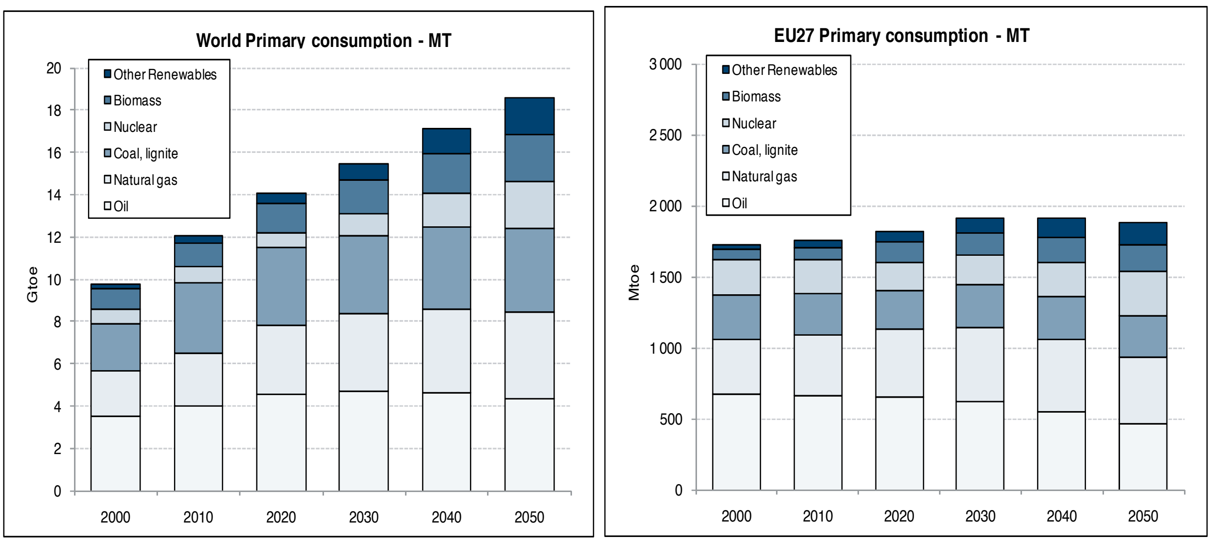
1.2. The Muddling Through Projection and the Comeback of Coal

The Muddling Through projection adopts exogenous forecasts for population and economic growth in the different world regions. In order to take into account the current financial and economic crisis, the latest SECURE Muddling Through case shows a global GDP growth rate in 2009 that is 50 percent lower than in the preceding POLES projections, with a catch-up to formerly considered growth rates in 2013. This corresponds to a world GDP that is in 2015 more than 5 percent lower than considered in previous POLES energy outlooks. This might, however, still be considered as an optimistic view on the capability of recovery of the world economy in the short-medium term. Other hypotheses on world economic growth might be explored through alternative runs of the model.

The projection is based on consistent assumptions on the availability of fossil energy resources and on the costs and performances of future technologies. In this kind of scenario, a standard discount rate of 8 percent is used to simulate investment decisions in the energy sector. Figure 2 describes the dynamics of the world and European energy system, in the initial settings considered in the Muddling Through.

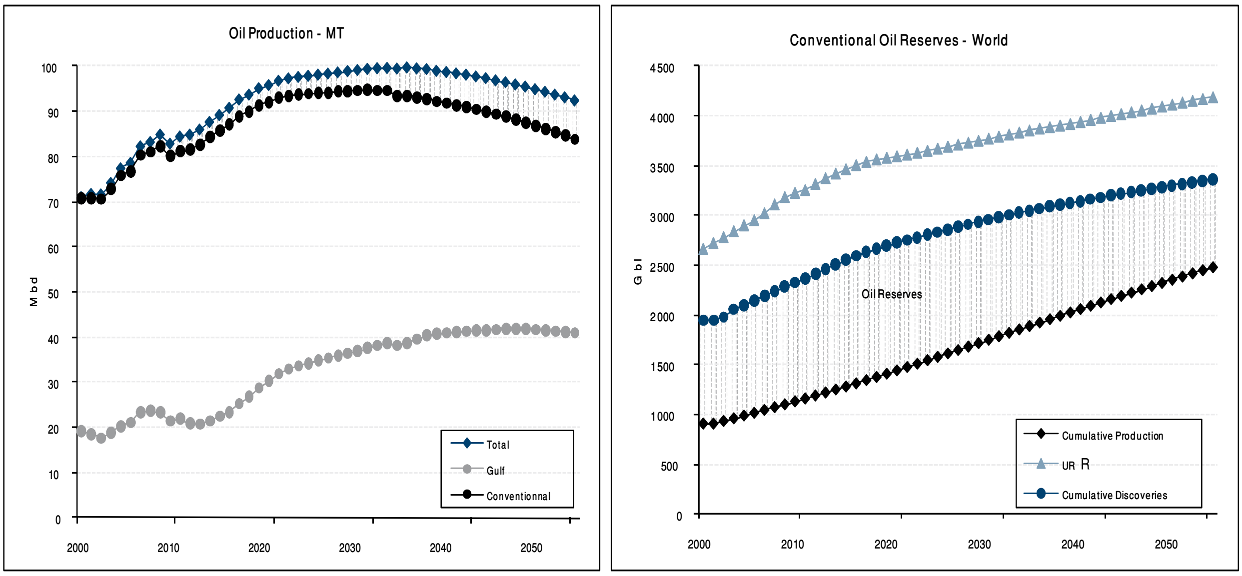
The key outcome of the Muddling Through case is almost a doubling of world energy consumption from 2000 to 2050, with a levelling-off of world oil and gas production after 2030. In spite of a significant development in nuclear energy, biomass and other renewables, which in 2050 represent more than one fourth of world Gross Inland Energy Consumption

Figure 2: Muddling Through Case – World (left) and Europe (right) Gross Inland Energy Consumption



Source: POLES model, LEPII, SECURE project

Figure 3: Muddling Through, Flows of World Oil Production (left), Stocks of Resources and Reserves (right)



Source: POLES model, LEPII, SECURE project

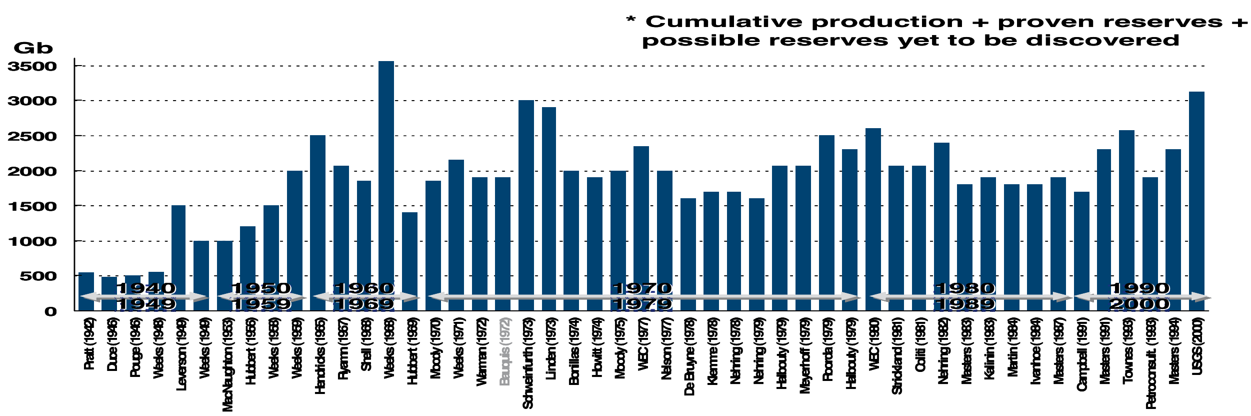
(GIEC), the primary source that most gains in importance is coal, which passes from 2.2 Gtoe to 4 Gtoe between 2000 and 2050. One can note that this is already much less than in the Business As Usual runs also performed in the SECURE project but not analyzed here. As for Europe, the dynamics in GIEC is much less pronounced with an increase from 1.7 Gtoe to only 1.9 Gtoe between 2000 and 2050. There again one notes a levelling-off of oil and gas consumption, the progress of renewables and the penetration of coal, although with a more modest magnitude than at world level.

1.3. The Probable Unsustainability of the Muddling Through: Upstream and Downstream Constraints

In many respects, however, this scenario is hardly sustainable in the long term. First of all, the level of oil production is high, peaking at slightly less than 100 Mbd in 2030 for conventional oil (Figure 3). This is a high level, which implies very high levels of total cumulative conventional oil production, from 900 Gbl in 2000 to 2,500 Gbl in 2050 (Figure 3).

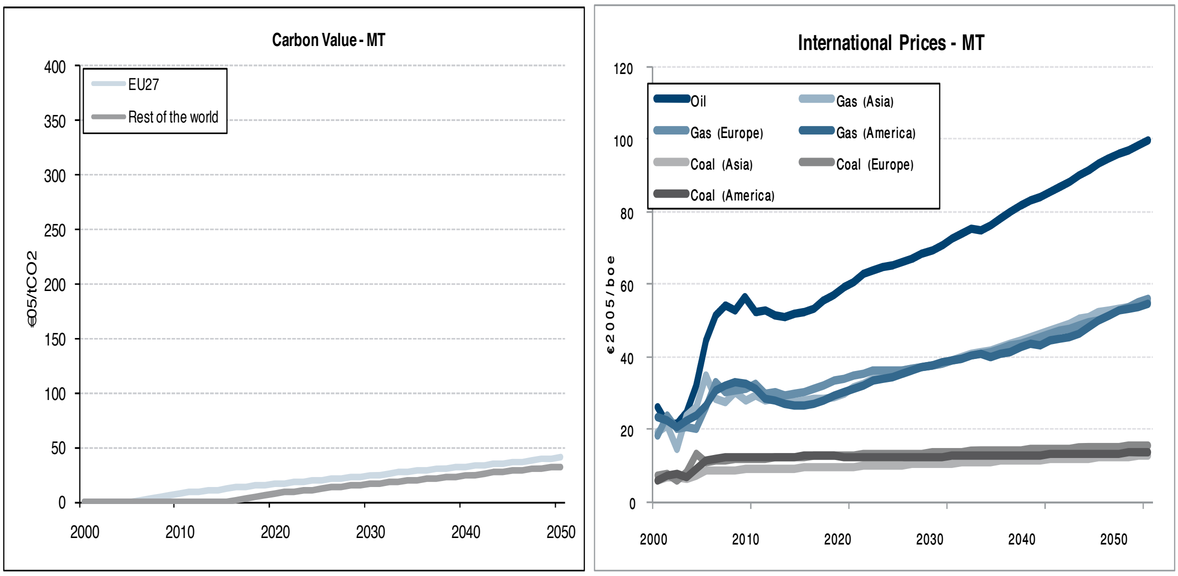
This is indeed a level that corresponds to the middle of the range of total Ultimate Recoverable

Figure 4: Estimates of Conventional Oil Ultimate Recoverable Resources



Source: P.R. Bauquis, 2006

Figure 5 : Carbon Value and International Energy Price Trajectories (MT)

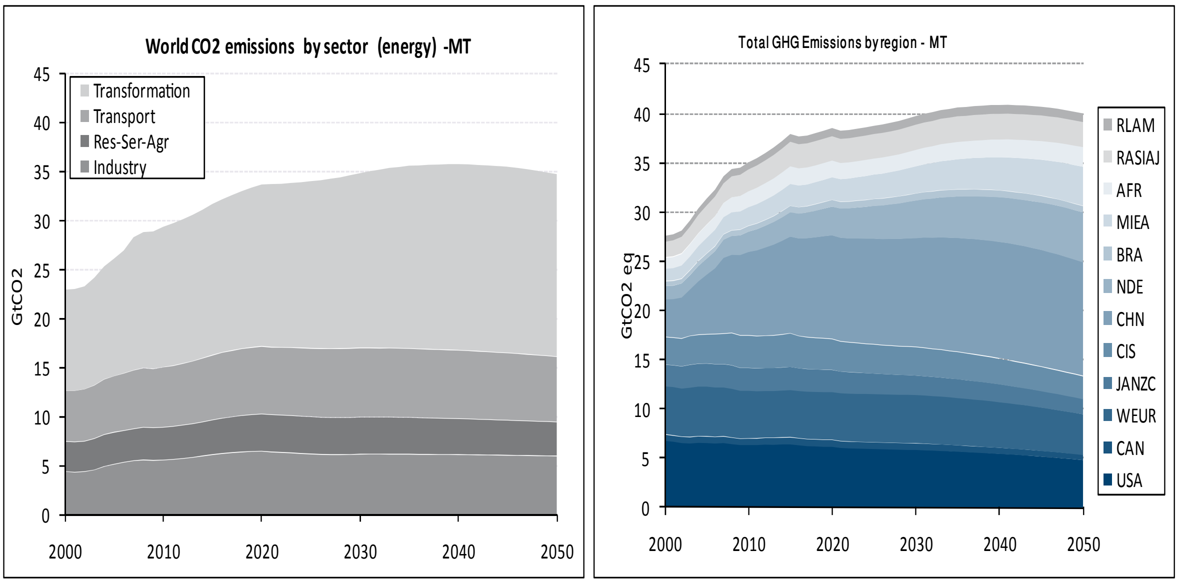


Source: POLES model, LEPII, SECURE project

Resources estimates for conventional liquids as identified by the Institut Français du Pétrole (Figure 4). Furthermore, it supposes about 3,500 Gbl of total cumulative discoveries in order to maintain a minimum level of reserves.

The consistency of the long run oil projections of the POLES model with the taking into account of resource limits is made possible by the expected increase of recoverable resources through significantly enhanced recovery rates in the different production regions. Nevertheless, the implied hypotheses for oil production in the Gulf region seems to be extremely optimistic as it supposes more than a doubling in 2030 and beyond. This increase in Gulf oil production to more than 40 Mbd from 2030 to 2050 is probably questionable,

Figure 6: World CO2 Emissions from Energy, by Sector and by Region



Source: POLES model, LEPII, SECURE project

Table 1: IPCC-AR4 Stabilization Scenarios

Category	Radiative forcing (W/m²)	CO_2 concentration[c] (ppm)	CO_2-eq concentration[c] (ppm)	Global mean temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity[b), c)] (°C)	Peaking year for CO_2 emissions[d]	Change in global CO_2 emissions in 2050 (% of 2000 emissions)[d]	No. of assessed scenarios
I	2.5-3.0	350-400	445-490	2.0-2.4	2000-2015	-85 to -50	6
II	3.0-3.5	400-440	490-535	2.4-2.8	2000-2020	-60 to -30	18
III	3.5-4.0	440-485	535-590	2.8-3.2	2010-2030	-30 to +5	21
IV	4.0-5.0	485-570	590-710	3.2-4.0	2020-2060	+10 to +60	118
V	5.0-6.0	570-660	710-855	4.0-4.9	2050-2080	+25 to +85	9
VI	6.0-7.5	660-790	855-1130	4.9-6.1	2060-2090	+90 to +140	5

Source: IPCC, AR4, SPM

not only from the resource and production capacity perspective, but also for reasons related to the geopolitical and internal political dimensions of the oil industry development in this region. This is why the smooth path for oil price increases that is associated with this scenario can be considered as a relatively optimistic hypothesis, although it ends at more than 100 €/bl in 2050, structurally (Figure 5).

The second reason for which the Muddling Through is probably not sustainable results from the implied CO2 emission level for the energy sector (Figure 6).

Emissions indeed double over the period considered, which would place this scenario in the very high range of the IPCC scenarios: a type VI scenario in the Table SPM.5 of AR4 (see Table 1), i.e. a mean temperature increase at equilibrium between 5 and 6°C.

2. Alternative Climate Policy Scenarios and Their Impacts on the International Energy Markets

Three scenarios are used in the SECURE study in order to characterize contrasted states of the world from the perspective of the "energy security and climate policy" nexus. They allow in particular the illustration of the consequences of differentiated energy policies on the fundamentals of the world energy system.

2.1. Alternative Scenario Definition

The Muddling Through with Europe Plus (MT E+) scenario supposes a failure in the efforts to develop a common framework of targets, rules and mechanisms for climate policies. Only weak domestic climate policies are implemented without any strong element of coordination of the different actions. But the case supposes that Europe goes beyond the mere Muddling Through policy, with a carbon value that is significantly rising from 8 €/tCO2 in 2010 to 89 €/tCO2 in 2050, instead of only 40 €/tCO2 in MT. The resulting picture is one of lower emissions in Europe than in the Muddling Through, but world emissions in 2050 are still above 51percent compared to 2000, which still corresponds to a Type IV scenario in the AR4 typology (see Table 2).

The third scenario, Europe Alone, supposes that Europe goes alone with a really stringent climate policy line, while the rest of the world continues on the same line as in Muddling Through. In that case it is supposed that the carbon value in the rest of the world is unchanged, while it is set in Europe at 178 €/tCO2 in 2050 (see Table 2).

Finally, the Global Regime scenarios correspond to the stabilization profile of GHG concentrations, below 450 ppmv for CO2 and 500 ppmv for all GHG gases. This is simulated through a world emission profile that ends up in 2050 at 50

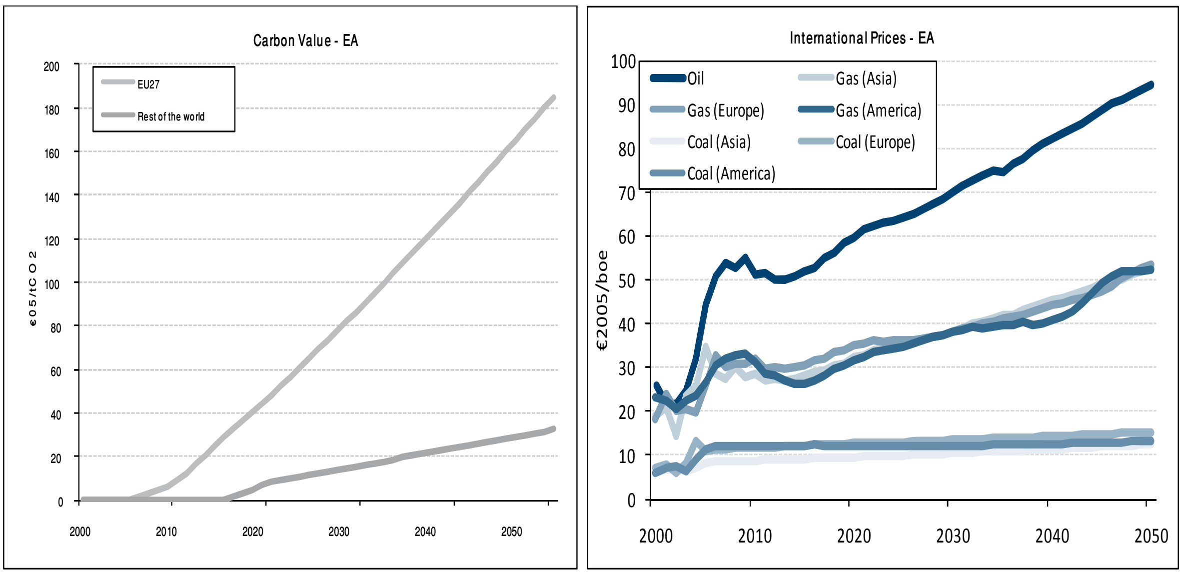
Table 2: Scenarios for Exploring the Energy Security – Climate Policy Nexus

	MT	EA	GR-2M	GR-FT
Scenario	**Muddling Through**	**Europe Alone**	**Global Regime with 2 Markets : Annex 1 + Non Annex 1**	**Global Regime with Full Trade**
Carbon Value (€/tCO2)	**EU** : 8 in 2010 40 in 2050 **RoW** : 10 years lag / EU	**EU** : 8 in 2010 178 in 2050 **RoW** : as in Muddling Through	**Ann 1** : 16 in 2010 392 in 2050 **Non Ann 1** : 1 in 2010 257 in 2050	**World** :7 in 2010 380 in 2050
EU27 CO2 emissions : 2020 / 1990 2050 / 1990	-4% -21%	-20% -60%		
Annex 1 CO2 emissions: 2020 / 1990 2050 / 1990			-25% /year 2000 -80% /year 2000	
World CO2 emissions : 2020 / 1990 2050 / 1990	+ 67% + 72%	+63% + 59%	127% /year 2000 - 50% /year 2000	127% /year 2000 - 50% /year 2000
AR4 Scenario Profile	Type IV > 600 CO2e	Type IV > 600 CO2e	Type II > 500 CO2e	Type II > 500 CO2e

Source: SECURE project

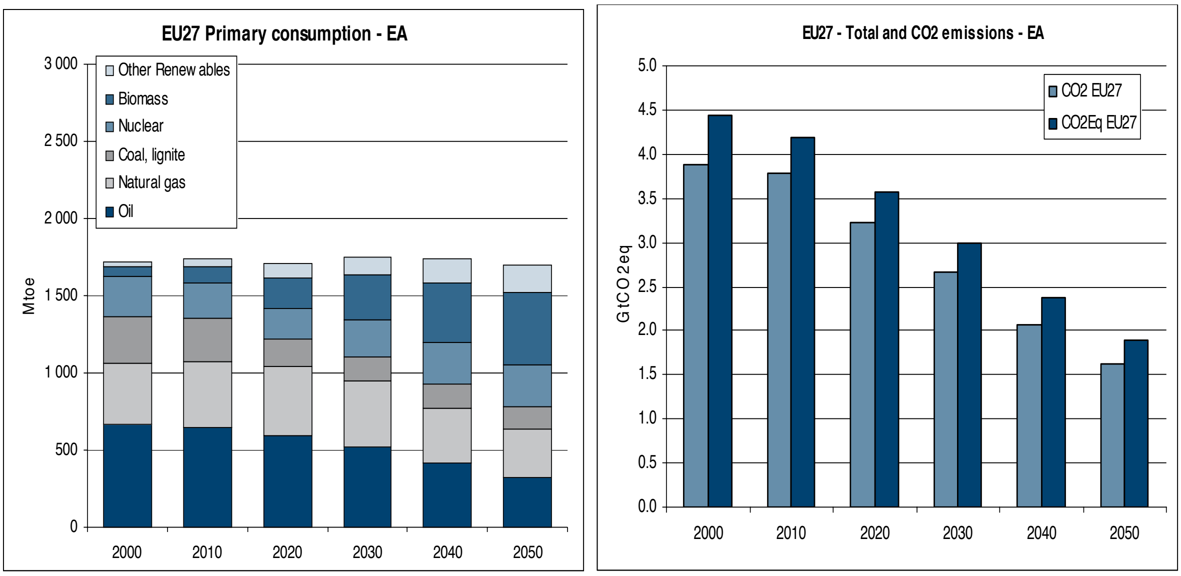
percent of 2000 CO_2 emissions. This is the Factor 2 reduction in 2050 emissions at world level, which is often advocated in international negotiations by the proponents of strong climate policies. In compliance with this global profile, two variants have been considered. In the Global Regime Two Markets (GR-2M) variant, the reductions in Annex I countries are set at -25 percent in 2020 and - 80 percent in 2050, compared to 2000. Reductions in the non-Annex I countries are determined as the residual for the global Factor 2 reduction. It corresponds to a case in which Annex 1 countries adopt a strong target and leave room for some emission increases in Non Annex 1 regions, as they do not use flexibility mechanisms to comply with this target. In the Global Regime Full Trade (GR-FT) variant, the same world emission profile is simulated while considering one world carbon price that is obtained either by a unified world carbon tax or by a global market for carbon emission trading.

Figure 7: Carbon Value and International Energy Price Trajectories (Europe Alone)



Source: POLES model, LEPII, SECURE project

Figure 8: Europe Gross Inland Energy Consumption and CO2 Emissions in Europe Alone



Source: POLES model, LEPII, SECURE project

2.2. Scenario Results

As the Muddling Through with Europe Plus scenario is an intermediate case aimed at covering the range of policies between Muddling Through and Europe Alone, we will leave this case aside and only provide a description of the consequences of the two most contrasted emission reduction scenarios, i.e. Europe Alone and Global Regime.

2.2.1. Europe Alone (EA)

This scenario aims at studying the impacts on the energy system of a strong climate policy in Europe, in spite a non-cooperative international framework with climate policies in the rest of the world that still correspond to the Muddling Through framework. In this setting, the carbon value at the end of the period is six times higher in Europe than in the rest of the world (Figure 7).

In this scenario, world gross inland consumption and international energy prices are hardly impacted compared to the preceding scenario, as Europe only represents a limited and diminishing fraction of the world energy system, i.e. 9 percent of total GIEC in 2050.

Conversely, in this scenario, the European energy system is profoundly altered by the introduction of a significant carbon value. Total energy consumption remains quite stable during the period. But the fuel-mix in total supply is quite different: fossil energy sources, which represent in 2000 79 percent of total GIEC are reduced to 71percent in 2020 and to 46 percent in 2050. The electricity system also incurs radical changes and is a major contributor to the reductions of carbon emissions in Europe (Figure 9).

Electricity production increases all over the projection period from 3,000 TWh in 2000 to 5,200 in 2050. This indicates that the electrification of the energy balance is one important dimension of emission abatement policies in the energy sector. This is easily explained by the following reasons: first, the penetration of non-CO2 power generation options allows reducing considerably the CO2 content of the average kWh; second, stimulated by the high carbon value, Carbon Capture and Storage (CCS) develops after 2020 and represents almost 47 percent of total thermal generation in 2050. This explains why electricity is almost carbon-free in Europe by the end of the projection period and why the role of the electricity sector is so prominent in emission abatement policies.

2.2.2. Global Climate Regime (GR)

The main feature of this scenario is the introduction of a global cap on emissions. The Global

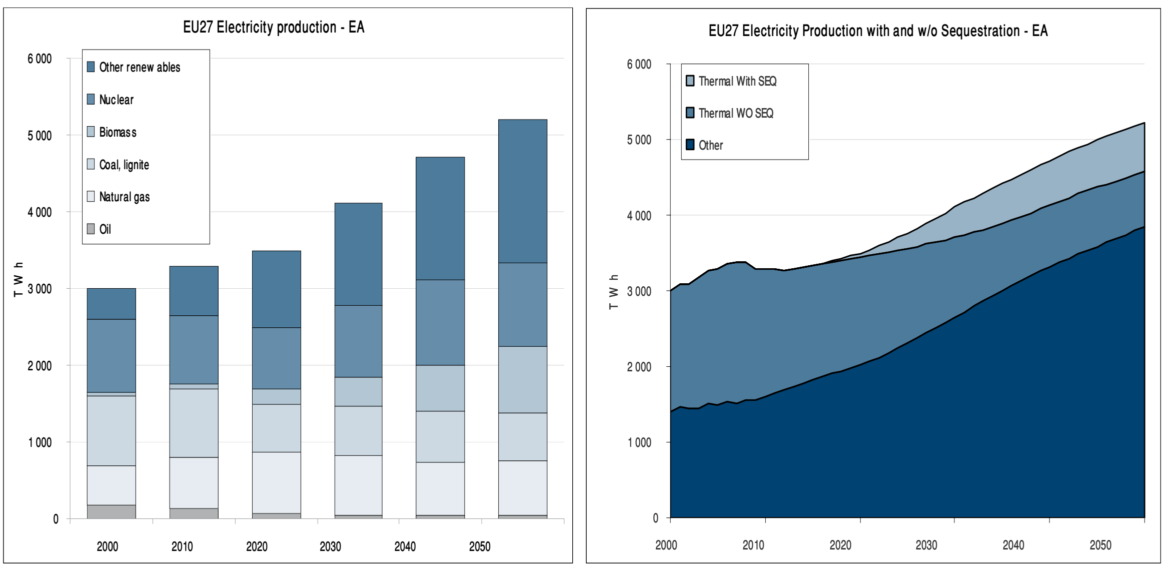
Regime scenario reflects a state of the world with ambitious climate targets, aiming at an emission profile of Type II in the AR4 typology. Emissions indeed double over the period considered, which would place this scenario in the very high range of the IPCC scenarios: a type VI scenario in the Table SPM.5 of AR4 (see Table 1), i.e. a mean temperature increase at equilibrium between 5 and 6°C (see Table 1). It allows stabilizing concentrations below 450 CO_2-only and 500 CO_2-equiv. and is indeed characterized by a 50 percent reduction in global emissions.

In the variant Global Regime with Two Markets (GR-TM), Annex 1 countries reduce their emissions by 25 percent in 2020 and 80 percent in 2050. These reductions are triggered by a rapidly increasing carbon value, which increases from 16 €/tCO_2 in 2010 to 68 €/tCO_2 in 2020 and to 392 €/tCO_2 in 2050. The corresponding carbon value in non-Annex 1 countries is significantly lower at 10 €/tCO_2 in 2020 and 257€/tCO_2 in 2050.

In the second variant, Global Regime with Full Trade (GR-FT), it is supposed that the abatement program follows the principle of the equalization of Marginal Abatement costs, as would result from the introduction of a unique carbon value, through a global carbon market or a unified international carbon tax. In this framework of hypotheses, the resulting carbon value increases rapidly to 28 €/tCO_2 in 2020, 73 in 2030, 178 in 2040 and 383 in 2050. One can emphasize the fact that the carbon value that is necessary to induce radically new trajectories in the world and European energy system is one order of magnitude higher than the value used in the Muddling Through, low intensity policy case. This corresponds to the fact that the Global Regime scenario reveals the need for radical changes in the energy systems: indeed 400 €/tCO_2 correspond approximately to one additional euro per litre of gasoline in typical European conditions.

While the European Gross Inland Energy Consumption and fuel-mix are not significantly different from the one simulated in Europe Alone (as presented in Figure 8), major changes occur in the global energy picture. World energy consumption is reduced by about one fourth compared to the one projected in the Muddling Through. As a result, the total amount of fossil fuels (coal, oil and gas) that is consumed at world level in 2050 is 8 percent lower than the one of 2000 (Figure 11). Due to its relatively low carbon content, natural gas consumption in 2050 is still higher than in 2000, but coal and oil consumption are lower.

Figure 9: Europe Electricity Generation Mix and Role of Carbon Capture and Storage in Europe Alone



Source: POLES model, LEPII, SECURE project

In order to reduce global emissions by 50 percent, this scenario supposes a significant development of Carbon Capture and Storage. By 2050, almost 44 percent of total gross emissions are captured, with almost 90 percent of CCS occurring in the electricity sector and the rest in industry and hydrogen production.

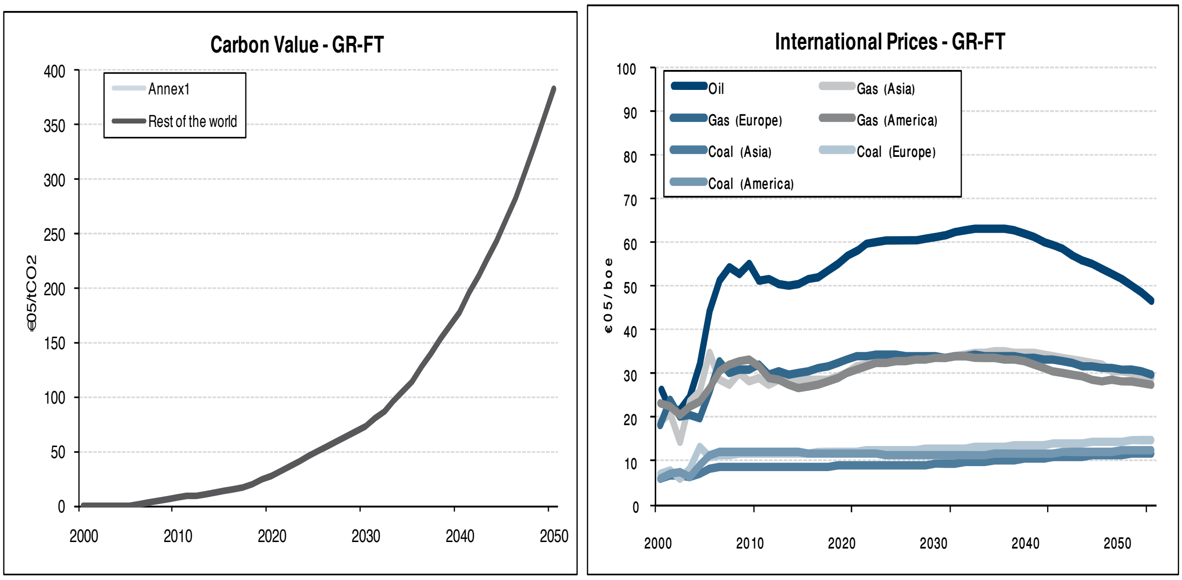
As a consequence of the low levels of consumption for the different fossil fuels in 2050 relatively to 2000, the prices of fossil fuels can be expected to be much lower in this scenario than in the *Muddling Through* or even *Europe Alone* scenarios. Indeed, the endogenous price mechanisms in the model result in a stabilization of international energy prices, at a level that is only 10 to 20 percent superior to current level, all along the projection period.

This leads to the main intermediate conclusion at this stage: climate policies, if they are ambitious and effective, will have a significant impact on the demand/supply balance for fossil fuels at the international level. In turn, this new balance of the global energy economy will certainly have significant impact on the range and variations in the international prices of coal, oil and gas. Even if exporting countries limit their investments and the capacity increases in order to maintain the price level, the anticipated tensions on the international markets regarding the risks of price hikes would be much reduced in all scenarios with strong and global climate policies.

3. Impacts on International Energy Trade and on Europe's Energy Security

In this section, we first analyze the consequences of the different scenarios in the perspective of Europe's dependence upon the international markets and consider the corresponding value of energy imports. In the second stage, we focus on natural gas imports and analyze the profile and sources of these imports in a geopolitical perspective.

Figure 10: Carbon Value Meeting the Emission Cap and Endogenous International Energy Prices in Global Regime (GR-full trade)

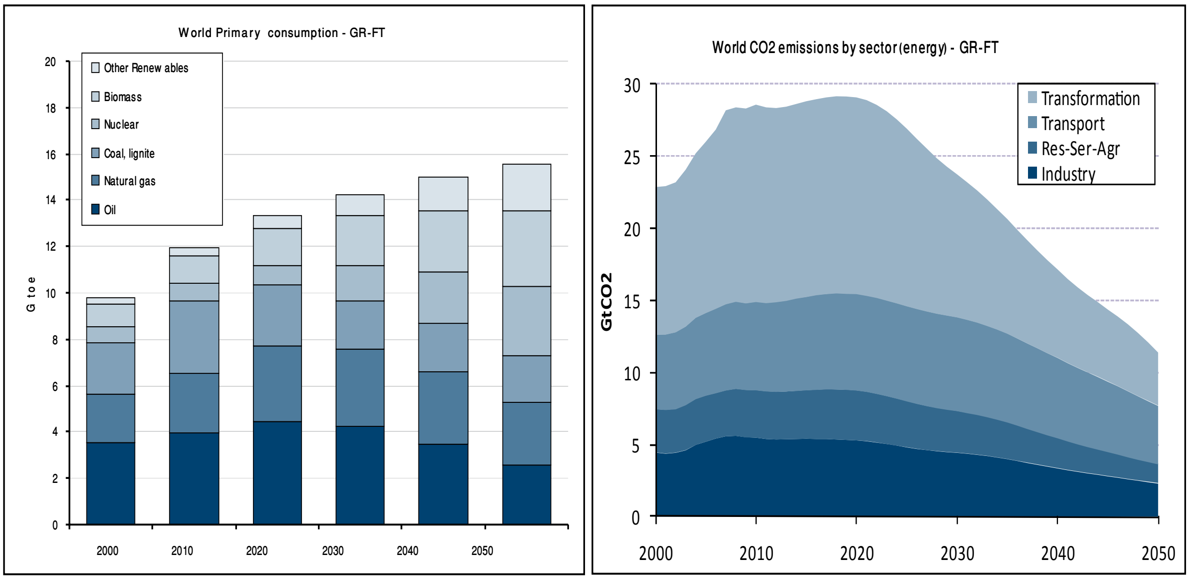


Source: POLES model, LEPII, SECURE project

3.1. World Oil Supply and Trade

The profile of oil production is an important feature of any long-term energy scenario. Because it is easy to transport, store and use, oil has been for many decades the "swing energy source" for balancing energy supply and demand. For that

Figure 11: World Gross Inland Consumption and CO_2 Emissions by Sector in the Global Regime (GR-FT)

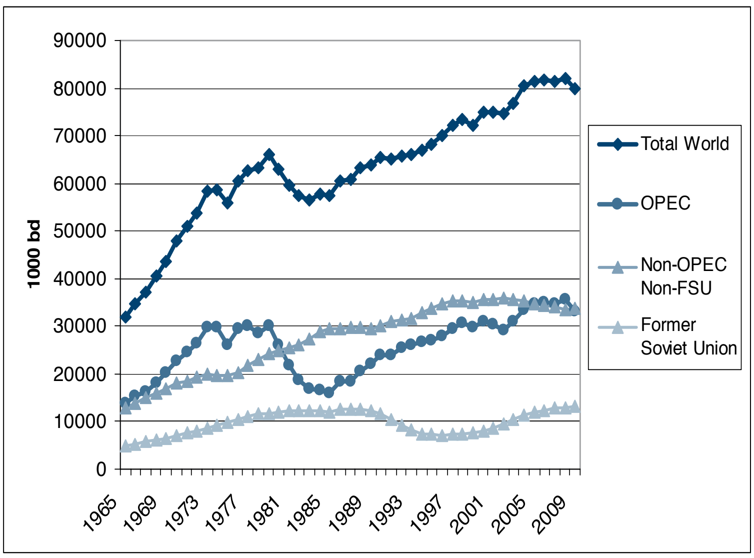


Source: POLES model, LEPII, SECURE project

reason, the price of oil often serves as a reference price for other energy sources. As discussed above, the Muddling Through projection suggests that this balancing role may become more problematic in the future, due to increasing difficulties in balancing oil demand and supply. According to the SECURE simulations, the world has emerged from a 20-year period of relatively cheap and abundant oil that began after the 1986 counter-shock. In the view of many observers and more recently also of insiders of the oil industry, the oil market in the next decade may undergo successive waves of structural changes that can be summarized as follows:

- In the short-term, the international market dynamics will be much influenced by the lack of surplus production capacity and by the peak in production in non-OPEC countries (a phenomenon that has been delayed in the past decade by production increases in the CIS).
- In the medium-term, the critical concern will be the extension of OPEC's countries production capacities well beyond their historic maximum (i.e. 35 Mbd in 2008).
- In the long-term, the peak in OPEC and Gulf production may constrain the global consumption of oil, even if non-conventional oil is strongly developed (as it is already in the Muddling Through case).
- This vision of the future of world oil is indeed consistent with a close analysis of recent trends in world oil production that clearly shows the levelling-off

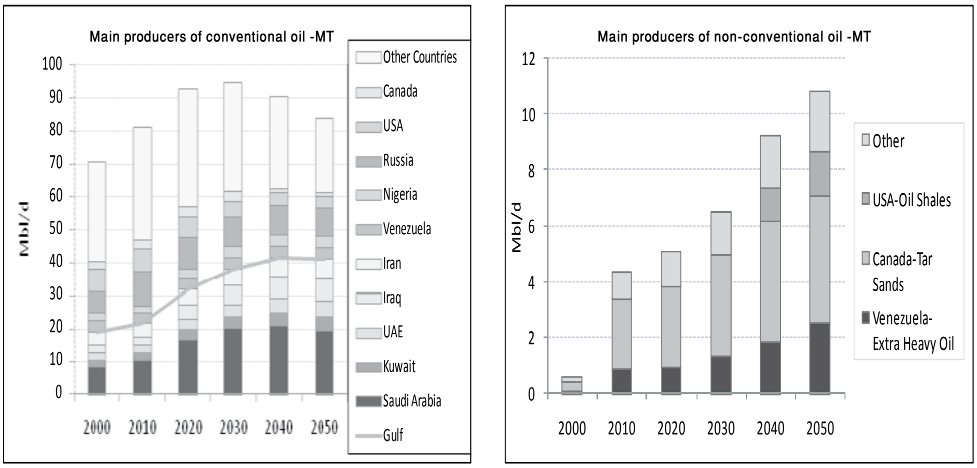
Figure 12: Oil Production, World and Main Regions, 1965-2009



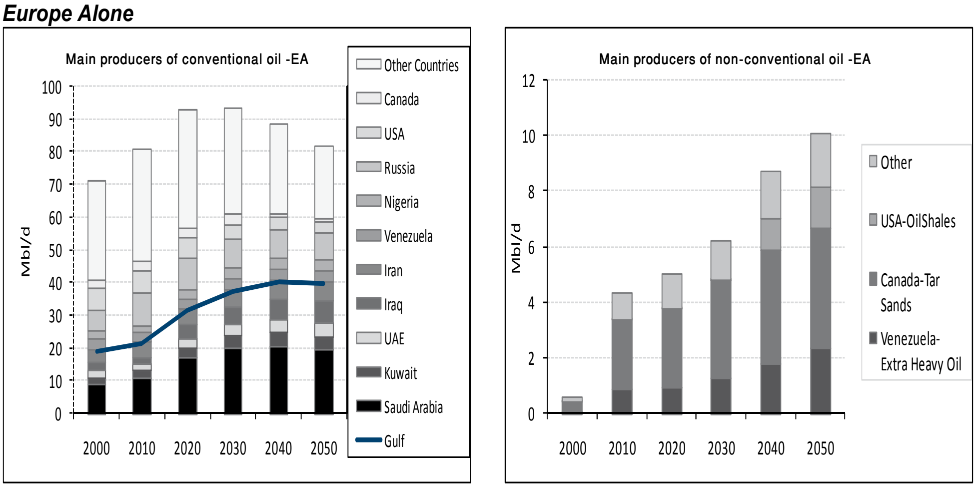
Source: BP Statistical Review 2010

Figure 13: Main Producers of Conventional Oil (left) and Non-Conventional Oil (right)

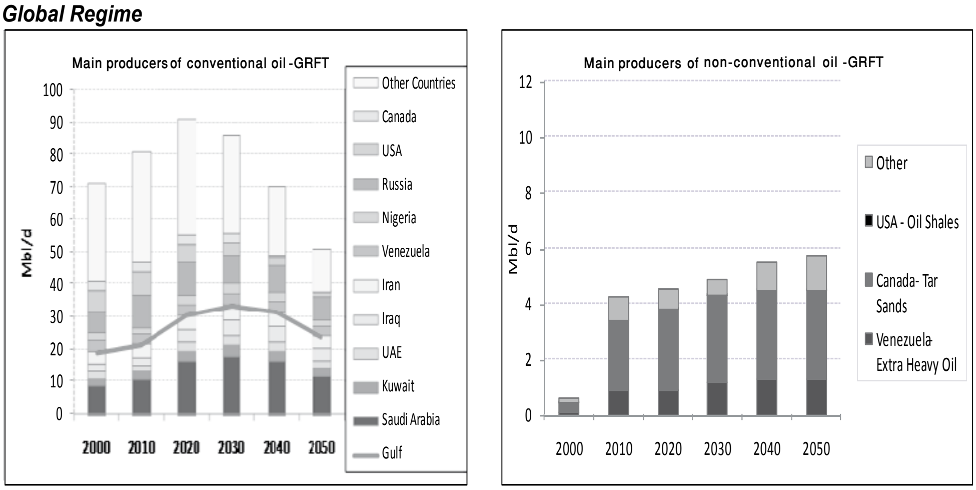
Muddling Through



Europe Alone



Global Regime



Source: POLES model, LEPII, SECURE project

of oil production in non-OPEC non-CIS regions (Figure 12)

The conventional and non-conventional oil production profiles in the Muddling Through SECURE scenario, as illustrated in the top row of Figure 13, describe the projection of world oil production in a setting of limited intensity climate policies:

- Non-OPEC production was still increasing before 2010 due to new capacities in the CIS (notably in Kazakhstan); between 2010 and 2020 it is stabilized at 48 Mbd but after that date it begins to decline to only 30 Mbd in 2050.
- As demand increase remains strong in the next decades, particularly in the emerging economies, the balance of supply and demand implies that production in both the Gulf and the rest of OPEC doubles from now to 2040 and then stabilizes until 2050.
- Similarly, the production of non-conventional oil, mostly from extra-heavy oil, tar sands and by the end of the projection also oil shales, becomes competitive and provides more than one tenth of total production in 2050.
- As a combination of these different trends, the production of conventional oil peaks at 95 Mbd in 2030, while non conventional oil represents at that date 6 Mbd. After 2030, conventional production progressively decreases to 83 Mbd in 2050, but part of the retreat in conventional oil is compensated by an increase in non conventional production to about 11 Mbd.
- The global oil production profile thus resembles the so-called oil plateau anticipated by many observers of the oil scene, with a maximum production after 2030 at 101 Mbd and then a slow decline to about 94 Mbd in 2050.

The world oil production profile is hardly affected by the introduction of a strong carbon constraint in the Europe Alone case (see Figure 13, middle row). Conventional oil production levels off between 2020 and 2030, while non conventional oil production is about 10 percent lower in 2050 than in the Muddling Through case.

The situation is, of course, very different in the Global Regime where conventional oil tops in 2020 with a strong decline after that date, while non-conventional oil hardly increases over the projection period (see Figure 13 bottom row). This is clearly the result of a "peak demand" introduced by strong carbon constraints in all world regions. High fossil fuel prices at consumer level are very high in that case due to the price of carbon, and oil demand is significantly reduced by the development of high efficiency and low emission options in transport (electric and hydrogen vehicles).

The increase in oil energy consumption upto 2050 appears to be limited even in the Muddling Through case. However, due to the general decline in non-OPEC production the international trade in oil increases from about 1.5 Gtoe today to more than 2.3 Gtoe in 2030 and 2040 (see Figure 14, where flows are measured between the main world regions). This is partly the consequence of the increase in consumption, but also of the concentration of production in the OPEC countries and more particularly the Gulf. In 2050, four regions are net exporters of oil, with the Middle East representing three-fourth of total exports. The other exporting regions are the CIS, Latin America and Africa. One can note the reduced imports of North America, which are due to the large supply of non-conventional oil from Canada. Again the world situation is hardly affected in the Europe Alone case.

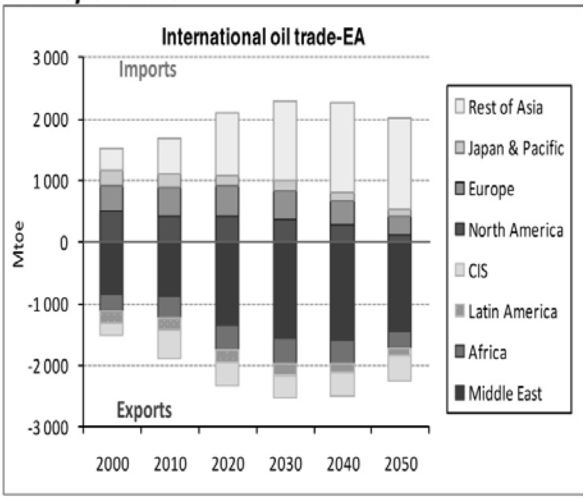
Finally, the consequences of the Global Regime can be synthesized as follows: while oil exports of the four structurally exporting regions are doubled in 2030 compared to 2000, the situation in 2050 is, to a large extent, a return to the 2000 situation, with almost unchanged market shares and a maintained dominance of the Middle East in total exports.

3.2 World Gas Supply, Trade and European Imports

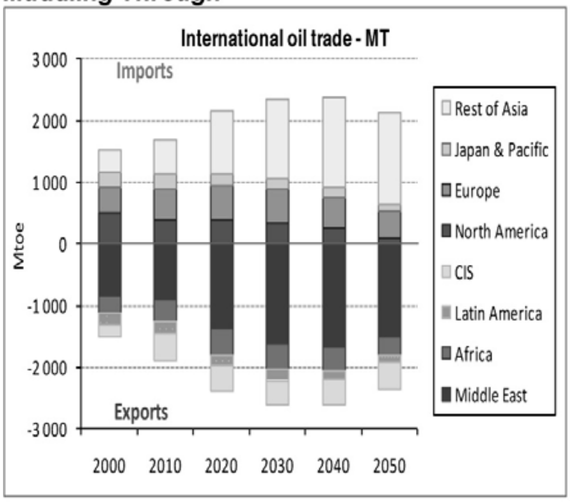
One of the key concerns regarding the long-term energy security of Europe is its dependence in terms of gas supply. Natural gas is a key resource, with new perspectives introduced by non-conventional shale gas. Its environmental characteristics are rather favorable, including in the context of GHG abatement policies, as gas-based electricity has a CO_2 content that is on average half of that of coal-based electricity (when no-capture and storage

Figure 14: International oil trade

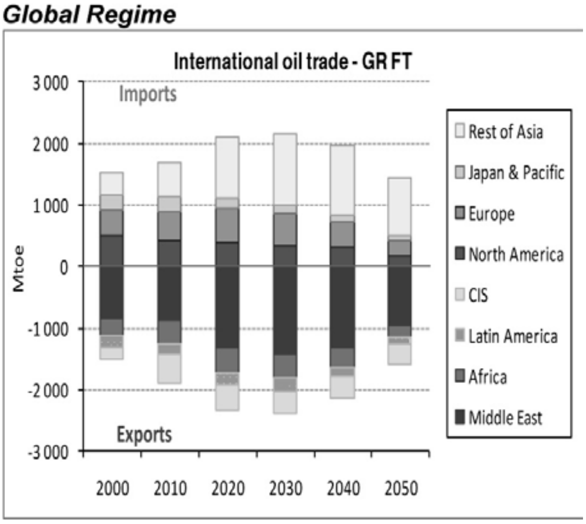
Europe Alone



Muddling Through



Global Regime



Source: POLES model, LEPII, SECURE project

option is considered). Natural gas also brings flexibility and diversification of energy supply at the transformation or end-use level.

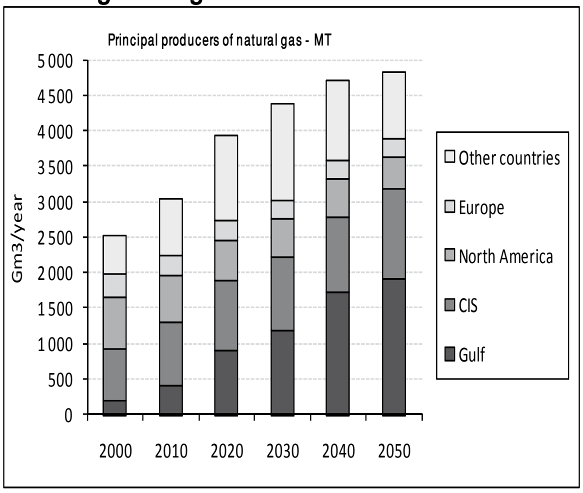
One of the key issues with natural gas supply is that of the transport infrastructure that is highly investment intensive whether in the form of gas pipelines or in terms of LNG facilities at exporting or importing points. The POLES model allows the description, with a relatively high level of detail, of the conditions of supply of the different regions of the world. It takes into account the key variables that explain the development of gas transport infrastructure, with an explicit description of the main routes and of their costs. These routes are developed endogenously, as a function of each region's demand, supply and gas market price, of the state of the reserves of the suppliers and of the transports costs, pipelines or LNG chains.

In the Muddling Through case, contrary to the oil situation, there is no peak gas before 2050, and by that date world gas production is about twice that of 2000, with 4.8 Bcm (see Figure 15). The Gulf and CIS regions will account for an increasing share of world production in the future, as European and North American production decreases in absolute terms. In particular, gas production in the Gulf region increases from 0.4 Bcm in 2010 to 1.9 Bcm in 2050. Again, the Europe Alone case does not introduce noticeable changes at the world level. Only in the Global Regime case is world gas production significantly impacted. However, there is still in that case, a significant increase in world gas production, from 3 Bcm in 2010 to 4 Bcm in 2050. The Gulf region and CIS are the main suppliers, with 35 percent each of world gas production.

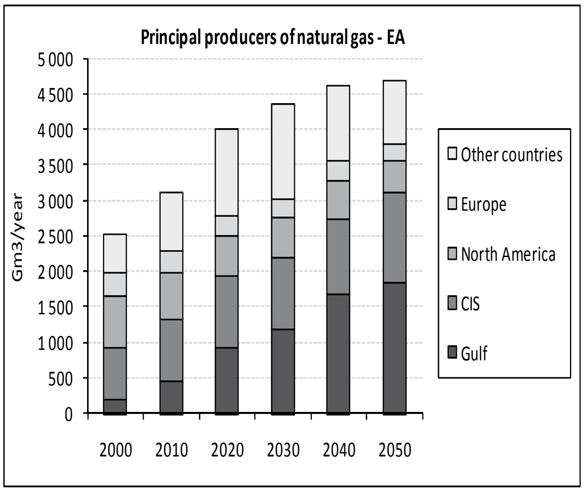
Inter-regional trade in gas increases considerably in the Muddling Through scenario as shown in Figure 16, from 0.2 Gtoe today to 1.5 Gtoe in 2050. These figures exclude intra-regional trade. The Middle East and the CIS are by far the largest exporters in 2050. The principal importing regions in 2050 are Asia, Europe and, to a lesser extent, North America; Africa is self-sufficient for its gas supply. The decrease of gas demand in other scenarios is accompanied by reduction of the imports to 1 Gtoe in 2050 in Global Regime.

Figure 15: Principal Producers of Natural Gas in the Four Scenarios

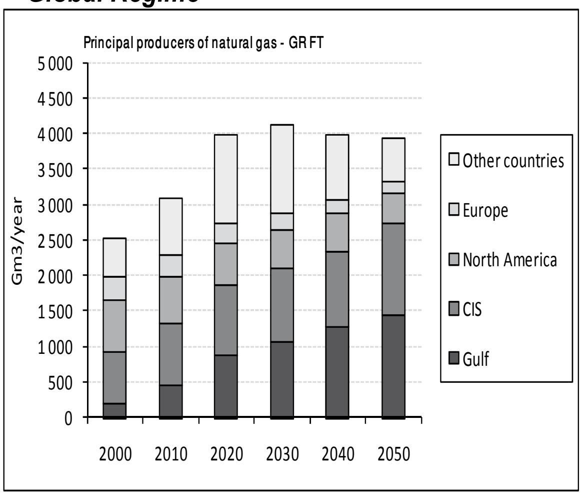
Muddling Through



Europe Alone



Global Regime



Source: POLES model, LEPII, SECURE project

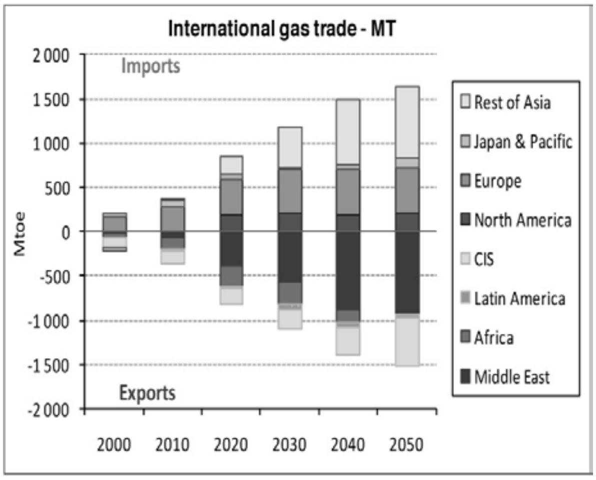
The simulation of different conditions of international energy markets and European energy system in the SECURE scenarios allows the display of very different profiles for Europe's future natural gas supply (Figure 17). In the Muddling Through scenario, Western Europe's total gas imports (i.e. gas consumption minus supplies from UK, Netherlands and Norway) are expected to increase dramatically over the next decades, from 200 Bcm to 650 Bcm in 2050. This happens, in spite of a total demand that is levelling off at about 700 Bcm between 2030 and 2040, but this is due to the reduction in regional domestic production from Norway, UK and Netherlands, which are divided by a factor of almost four between 2000 and 2050, from 240 to 50 Bcm. While supply from Russia increases from 130 Bcm to 219-226 Bcm in these two scenarios, European gas supply also increasingly depends on new supplies from Nigeria, the Commonwealth of Independent States (mostly Kazakhstan), and Iran.

The picture is quite different in the *Europe Alone* and *Global Regime* cases: due to the carbon constraint, total gas demand of Western Europe is much lower after 2020 than in the two preceding cases. In 2050, it is even lower than in 2000 with about 400 Bcm in *Global Regime* scenario. To a large extent, this reduction of total demand weighs on the new suppliers that would play an important role in the *Muddling Through* scenario, i.e. Saudi Arabia, Venezuela, Nigeria, Kazakhstan and Iran. Imports from Russia still represent about 200 Bcm in 2050 in both scenarios.

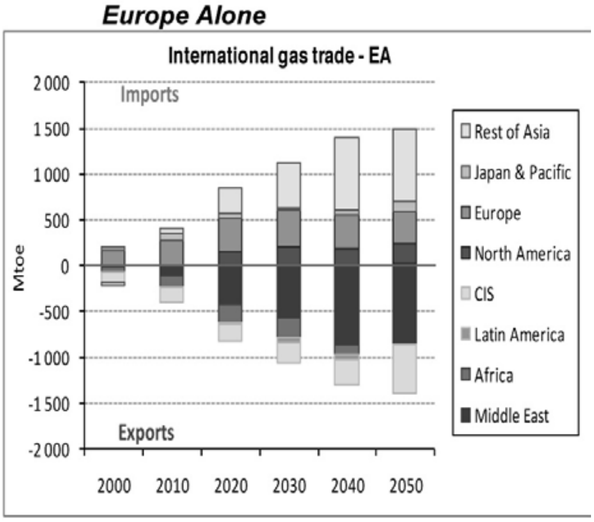
In conclusion of this analysis of long-term natural gas supply of Europe, one has indeed to emphasize the fact that the volume of Russian exports to Europe appear to be relatively stable in the different scenarios, at least until 2040, when they reach a level of about 200 Bcm in the four cases. Only after that date do the results differ significantly, with exports that are 30 to 40 percent higher in the Muddling Through than in the Europe Alone and Global Regime scenarios. Russia seems, however, to keep a comparative advantage in the supply of Europe in the carbon constraint cases.

Figure 16: International Gas Trade

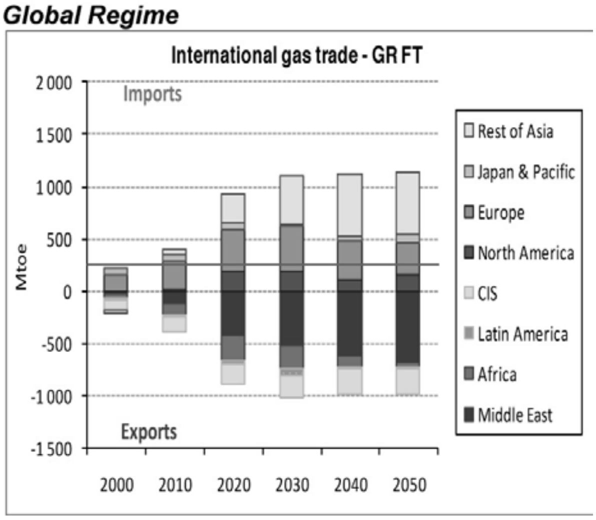
Muddling Through



Europe Alone



Global Regime



Source: POLES model, LEPII, SECURE project

3.3. World Coal Supply and Trade

In spite of resources that are more widely distributed than those of oil and gas, international coal trade doubles over the projection period in the Muddling Through (Figure 18) scenario. The high volume of trade reflects the strong comeback of coal in a double context of relative scarcity and high prices of oil and gas, accompanied by only moderate GHG emission constraints. The situation changes in the Europe Alone and Global Regime scenarios. Coal trade remains almost stable during the period in the Europe Alone scenario and it even decreases compared to current levels in the Global Regime scenario.

Europe remains the major importer, representing more than 80 percent of net imports during the whole period in all scenarios except in the Europe Alone case, in which other world regions continue to intensively use coal. However, European coal imports shrink from the Muddling Through scenario to the others, due to changes in the structure of the electricity generation and final consumption in favor of decarbonised energies and cleaner technologies.

The four main exporting regions are North America, the Pacific, Africa and the CIS. Because of the rapid growth in consumption, Asia becomes a net importer late in the period. Their share remains nearly stable, while the volume diminishes in the Europe Alone and Global Regime scenarios.

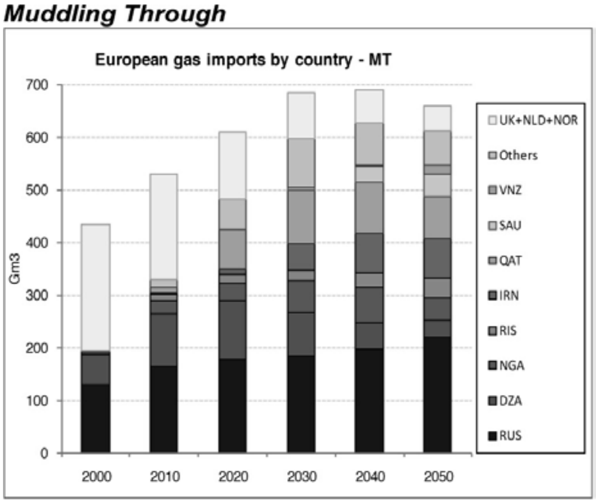
3.4. Consequences for Europe's Energy Dependence and Value of Imports

The scenarios presented above result in very different profiles for energy imports and dependence. The Muddling Through corresponds to the scenario with higher consumption, imports, dependence rate and value of energy imports. While Europe's global import dependence rate was of 50 percent in 2005 and the value of energy imports of 236 G€ in 2005, these figures rise respectively to 57 percent and 351 G€ in 2020 and 53 percent and 491 G€ in 2050 (Table 3, upper row).

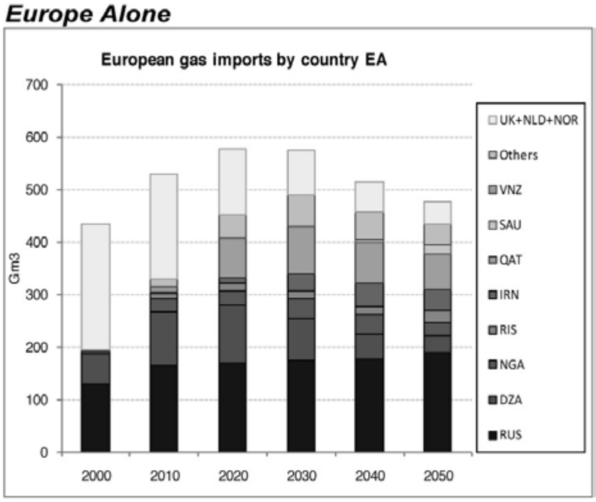
The Europe Alone scenario presents interesting characteristics, as it is the one with the lowest level of energy imports in terms of volume and dependence rate. This can be easily explained as this

Figure 17: Europe's Natural Gas Supplies in the Four Scenarios

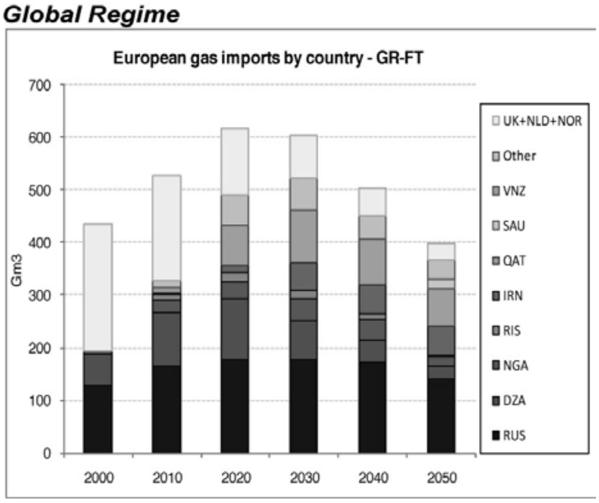
Muddling Through



Europe Alone



Global Regime



Source: POLES model, LEPII, SECURE project

case combines a stringent emission reduction policy in Europe, while the rest of the world continues along a line of modest climate policy. In that case, the global demand and prices for fossil fuels remain high and this not only limits demand in Europe but also stimulates domestic supply. The value of total energy imports is more than halved in the Europe Alone scenario in 2050, compared to the Muddling Through. One key outcome of the study is thus that a strong European climate policy may create a double dividend in terms of energy security, even in the case of weak global climate coordination.

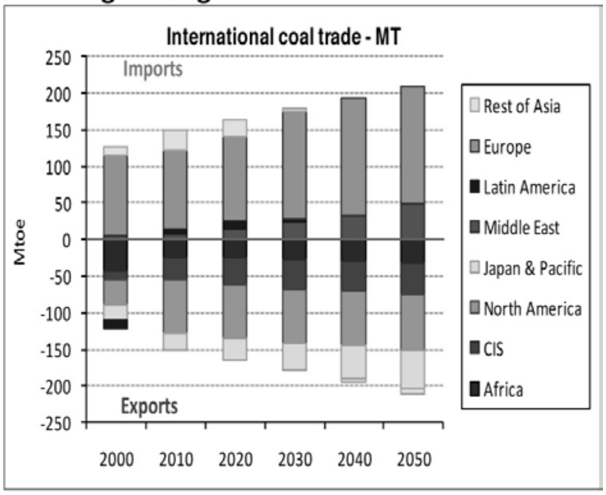
Finally, the Global Regime scenario illustrates a fully different future for the world energy system, with lower global fossil fuel demand and prices. Europe's energy imports are similar in quantities compared to the Europe Alone case described above. But oil and gas prices are significantly lower and, as a consequence, the value of imports is at its lowest level: 144 G€ only in 2050, against 491 G€ in the Muddling Through scenario.

Conclusion

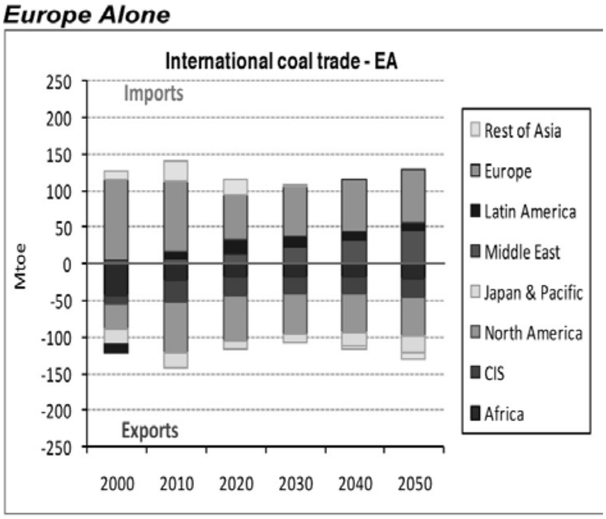
The scenario exercises developed in the SECURE project allow the illustration of the complex interactions of climate policies and energy security issues. They show in particular that the Muddling Through scenario, with low intensity and non-coordinated climate policy does not represent a really sustainable energy future. This is because of the double constraint that impends on the world energy system: upstream through the limitations in oil and gas availability and downstream, by the limited storage capacity of the atmosphere for GHGs. The low carbon price does already change significantly the level of emissions through reduced demand, accelerated development of non-fossil energy sources and some development of Carbon Capture and Storage. But this is not sufficient to meet the emission targets that are considered as desirable in IPCC AR2 in order to limit average temperature increase at level of 2°C compared to the pre-industrial situation. Moreover, this scenario neither significantly alters the balance of demand or supply on the international energy markets, although it alleviates somewhat the potential tensions.

Figure 18: International Coal Trade

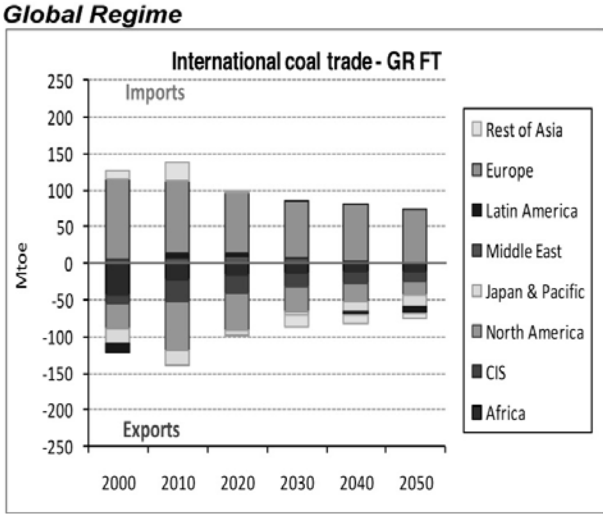
Muddling Through



Europe Alone



Global Regime



Source: POLES model, LEPII, SECURE project

The Global Regime scenario clearly allows the improvement of the situation from these two perspectives, of reducing both emissions and the level of tension on international hydrocarbon markets, through lower oil and gas production. This is a potential double dividend situation, probably the most important one to be derived from ambitious climate policies. Finally, the Europe Alone scenario does not meet the climate target as the impacts of ambitious policies in Europe are not sufficient to compensate for the massive global emission increases in the rest of the world. However, in this scenario setting, there is still an element that is strongly beneficial for Europe:

- Imposing strong emission reduction domestically results in a thorough restructuring of the European energy system.
- While it is supposed in this scenario that other countries adopt a free-riding behavior and do not trigger such a restructuring, it is probable that tensions on the oil and gas market would remain high, with risks of repeated shocks in the near- and long-term future.
- In that case, Europe would be protected from these external shocks by lower energy demand, higher contribution of domestic non-fossil fuels (renewable and nuclear), and a much lower level of fossil fuel imports.

Would this reward of ambitious climate policies fully compensate for the extra costs of the energy system restructuring? This question remains open today, but future developments in the SECURE project may help to better appreciate the magnitude of the risk avoided through virtuous climate policy in a non-cooperative international context. Table 4 intends to illustrate the fundamentals of the risks associated for a country (c) to a negative event (e) and develops the risks in the three archetypal scenarios examined in this study.

It comes out of this study that an ambitious policy would bring to Europe a double dividend in its capacity to develop a new energy model – adjusted to sound climate policies – and in the resulting lower vulnerability to potential shocks on the international energy markets. Hence, it appears that it would probably be in the interest of Europe to implement

Table 3: Profiles for Europe Energy Imports and Dependence in Three Contrasted Scenarios

Muddling through

MT Results - EU27		1990	2000	2005	2010	2020	2030	2040	2050
GIC (Mtoe)		1531	1725	1822	1759	1820	1911	1909	1881
Imports (Mtoe)	Coal, lignite	-72	-94	-107	-95	-96	-132	-144	-146
	Oil	-464	-505	-557	-532	-543	-537	-475	-399
	Natural gas	-112	-180	-250	-298	-399	-471	-473	-448
Dependance rate	Coal, lignite	17%	30%	35%	32%	35%	44%	48%	50%
	Oil	79%	76%	82%	81%	83%	86%	86%	85%
	Natural gas	45%	46%	56%	69%	83%	91%	94%	96%
	Total	42%	45%	50%	53%	57%	60%	57%	53%
International prices (€05/boe)	Coal	11.8	7.2	10.9	11.8	12.8	13.6	14.5	15.4
	Oil	24.9	25.9	44.2	51.9	60.5	72.2	85.2	99.6
	Gas	14.0	18.3	25.8	32.2	34.7	38.8	46.1	55.8
Value of imports (G€05)	Coal, lignite	6.2	4.9	8.6	8.2	9.0	13.2	15.3	16.4
	Oil	84.5	96.1	180.4	202.7	240.7	284.4	296.6	291.3
	Natural gas	11.5	24.1	47.3	70.3	101.5	133.8	160.1	183.1
	Total	102.3	125.1	236.3	281.2	351.2	431.5	472.1	490.9

Europe Alone

EA Results - EU27		1990	2000	2005	2010	2020	2030	2040	2050
GIC (Mtoe)		1531	1725	1822	1740	1705	1756	1738	1700
Imports (Mtoe)	Coal, lignite	-72	-94	-107	-86	-46	-55	-59	-60
	Oil	-464	-505	-557	-522	-490	-440	-344	-255
	Natural gas	-112	-180	-250	-295	-366	-373	-324	-295
Dependance rate	Coal, lignite	17%	30%	35%	31%	27%	34%	38%	42%
	Oil	79%	76%	82%	81%	82%	84%	82%	79%
	Natural gas	45%	46%	56%	69%	82%	88%	91%	94%
	Total	42%	45%	50%	52%	53%	49%	42%	36%
International prices (€05/boe)	Coal	11.8	7.2	10.9	11.7	12.7	13.4	14.3	15.2
	Oil	24.9	25.9	44.2	51.0	59.7	70.1	82.1	94.6
	Gas	14.0	18.3	25.8	31.8	35.1	38.1	44.2	53.5
Value of imports (G€05)	Coal, lignite	6.2	4.9	8.6	7.3	4.2	5.4	6.2	6.7
	Oil	84.5	96.1	180.4	195.4	214.5	226.0	206.9	177.1
	Natural gas	11.5	24.1	47.3	68.8	94.2	104.1	105.1	115.7
	Total	102.3	125.1	236.3	271.5	313.0	335.5	318.2	299.6

Global Regime

GR-FT Results - EU27		1990	2000	2005	2010	2020	2030	2040	2050
GIC (Mtoe)		1531	1725	1822	1747	1801	1841	1781	1698
Imports (Mtoe)	Coal, lignite	-72	-94	-107	-91	-73	-73	-73	-68
	Oil	-464	-505	-557	-525	-527	-475	-357	-233
	Natural gas	-112	-180	-250	-293	-397	-407	-341	-271
Dependance rate	Coal, lignite	17%	30%	35%	32%	33%	39%	42%	44%
	Oil	79%	76%	82%	81%	83%	86%	86%	84%
	Natural gas	45%	46%	56%	69%	83%	90%	93%	97%
	Total	42%	45%	50%	52%	55%	52%	43%	34%
International prices (€05/boe)	Coal	11.8	10.9	11.6	12.2	12.9	13.9	14.8	14.8
	Oil	24.9	44.2	51.1	57.9	61.9	59.1	46.4	44.6
	Gas	14.0	25.8	31.9	33.8	33.8	33.0	29.8	30.1
Value of imports (G€05)	Coal, lignite	6.2	7.5	9.2	8.1	7.0	7.5	8.0	7.3
	Oil	84.5	163.5	208.7	222.7	239.1	205.9	121.6	76.3
	Natural gas	11.5	34.0	58.5	72.6	98.5	98.6	74.4	59.9
	Total	102.3	205.0	276.4	303.4	344.6	312.0	203.9	143.5

Source: POLES model, LEPII, SECURE project

Table 4: Risk as the Vulnerability to an Adverse Event

$Risk_{c/e}$ =	$Probability_e$	x $Magnitude_e$	x $Vulnerability_{c/e}$
Muddling Through	**High**	**High**	**High**
Europe Alone	**High**	**High**	**Low**
Global Regime	**Low**	**Low**	**Low**

the ambitious policy that is part of the Climate and Energy Package of 2008.

Of course, this raises the issue of how to develop cooperative relations with oil- and gas-exporting countries, who on their part may wish to benefit from a certain degree of security of demand. Exchanges and discussions on long-term energy scenarios – however fragile and uncertain these scenarios remain – may help in an improved mutual understanding of the goals that are pursued by both categories of countries in the development of their energy policies. In that way, scenarios can be useful tools to develop a somewhat stabilized framework for the investment decisions that in any case will be necessary to ensure the long-term energy supply of the different world regions.

References

- Adelman, Morris A. 2004. The real oil problem. *Regulation*, Spring 2004.
- Adelman, Morris A. 1990. Mineral depletion, with special reference to petroleum. *The Review of Economics and Statistics* 7 (no.1):1-10.
- Aleklett, Kjell & al. 2010. The peak of the oil age – Analyzing the world oil production reference scenario in World Energy Outlook 2008. *Energy Policy* 38: 1398-1414.
- Babusiaux, Denis, and Pierre-René Bauquis, A double oil shock scenario. March 30, 2008, ENSPM, Paris EU Energy Policy blog, http://www.energypolicyblog.com/2008/03/30/a-double-oil-shock-scenario/
- Criqui, P., Mima, S. 2009. Exploring the energy security and climate policy nexus with the POLES energy model in the SECURE project. Communication à *International energy workshop*. Venise, 17-19 juin 2009.
- De Almeida, Pedro and Silva Pedro D. 2009. The peak of oil production – Timings and market recognition. *Energy Policy* 37: 1267-1276.
- De Castro, Carlos, Miguel Luis Javier & Mediavilla Margarita. 2009. The role of non conventional oil in the attenuation of peak oil. Energy Policy 37 (no. 5): 1825-1833.
- Eskeland, G., Criqui, P., Jochem, E., Neufeld, H. , Mima, S., collab., et al. 2010. Transforming the European energy system. In *Making climate change work for us*, Chap. 7, eds. M. Hulme, H. Neufeld. 165-199. Cambridge: Cambridge University Press.
- Forbes, Sarah. 2009. *Community engagement for CCS*. World Resources Institute. April 23, www.wri.org
- Knopf, B., Edenhofer, O., Criqui, P., collab., Mima, S., collab., et al. 2010. The economics of low stabilisation: implications for technological change and policy. In Making climate change work for us. Chap. 11, eds. M. Hulme, H. Neufeld, 291-318. Cambridge: Cambridge University Press.
- Hemmingsen, Emma. 2010., "At the base of Hubbert's Peak: Grounding the debate on petroleum scarcity. Geoforum, 10p.
- International Energy Agency. 2008., *World Energy Outlook* 2008, OECD-IEA, Paris.
- Mabro, Robert. 2010. On oil peak or peaks. *Oxford Energy Journal*, Issue 80: 9-11.
- Mabro, Robert. 2006. The peak oil theory. *Oxford Energy Comment*, September 2006.
- Maggio G. & Cacciola G. 2009. A variant of the Hubbert Curve for world oil production forecasts. *Energy Policy* 37 (no.11): 4761-4770.
- Markandya, A., B. Armstrong, S. Hales, A. Chiabai, P. Criqui, S. Mima, C. Tonne, P. Wilkinson. 2009. Impact on public health of strategies to reduce greenhouse gases: low carbon electricity generation. *The Lancet* 374 (no. 9706) : 2006-2015.
- Masset, Jean-Marie (avec les contributions de P-R Bauquis, D. Gautier & A. Perrodon) .2009., Pétrole, Gaz : pic ou plateau. *Revue de l'énergie*, no. 591 (Oct): 318-325.
- Matutinovic, Igor. 2009. Oil and the political economy of energy. *Energy Policy* 37 (no. 11): 4251-4258.
- Mohr, S. H. and G.M. Evans. 2010. Long term prediction of unconventional oil production. Energy Policy 38: 265-276.
- Odell, Peter R. 2003. The global energy outlook for the 21st century. Lecture given in Wassenaar, May 21.
- Porter, Edward D. 1995. Are we running out of oil? Discussion Paper #081, American Petroleum Institute.

- Stevens, Paul. 2009. *The coming oil supply crunch*, Chatham House Report, London.
- Wells, Peter, R. A. 2005. Oil supply challenges -1: The non-OPEC decline. *Oil & Gas Journal*, February 21.
- Wells, Peter, R. A. 2005. Oil supply challenges -2: What can OPEC deliver? *Oil & Gas Journal*, March 7.
- Zecca, Antonio and Luca Chiari. 2010. Fossil-fuel constraints on global warming. *Energy Policy* 38: 1-3.
- Zhao, Lin, Lianyong Feng, A.S. Charles Hall. 2009. Is peakoilism coming? *Energy Policy* 37 (no. 6): 2136-2138.

Threats to Oil Supply Security*

Introduction

Threats to oil supply security are potentially numerous, and the discussion can only be fruitful if different kinds of threats are considered separately and the potential significance of each is assessed. It is not difficult to bundle several kinds of threats in a single, all-encompassing statement – but is this a realistic approach? Not all threats materialize at the same time, not all combine to determine catastrophic consequences.

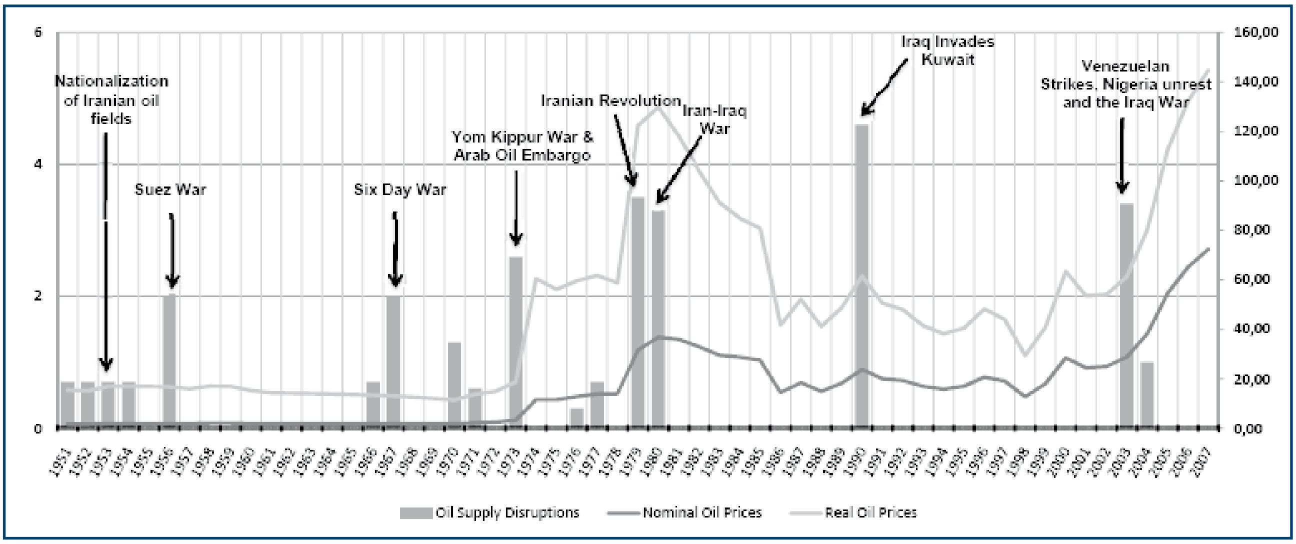
In this paper, we shall follow an analytical approach and distinguish different types of threats. The primary distinction is between geopolitical and military threats: the former are linked to political developments and the adoption or reform of policies affecting oil production and exports. The latter are linked to the use of military force or violence on the part of either state or non-state actors.

A third section of the paper deals specifically with potential threats to oil transportation on the high seas.

The literature on oil supply interruptions has developed a fairly universally accepted list of historical events that are characterized as "major disruptions." Figure 1, from the Energy Information Administration of the US, illustrates these events.

There are eight events in total considered in this figure, of which five are international conflicts, two are domestic political events, and one is a combination of the two. A slightly different listing is proposed by the International Energy Agency:[1] the IEA's list excludes the Iranian nationalization of 1951-54, includes the Iraqi export suspension of 2001 as well as the impact

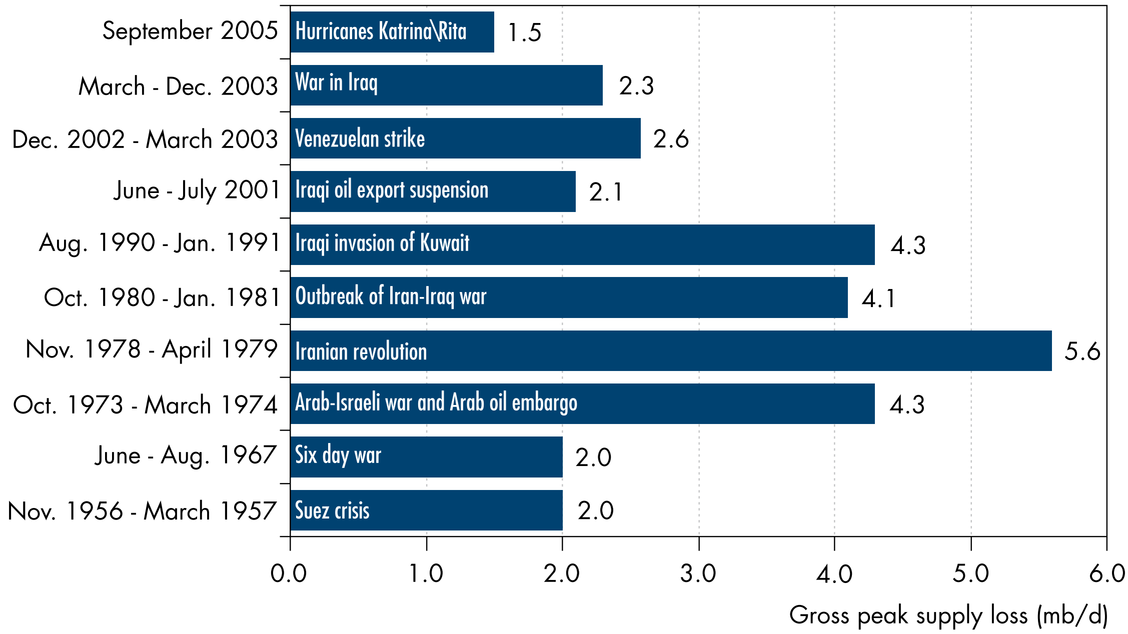
Figure 1: Major Oil Supply Disruptions and Price Impact



Source: Energy Information Administration, US

** This paper was written by Giacomo Luciani with support from François-Loïc Henry of GRCF*

Figure 2: Major World Oil Supply Disruptions



- The most significant oil supply disruptions in recent decades have occurred in the Middle East, the largest of which was associated with the 1978 Iranian revolution.
- More recently, in early 2003, the market suffered disruptions from overlapping events: the effects of a strike at the national oil company in Venezuela and the outbreak of war in Iraq were exacerbated by strikes in Nigeria.

Source: International Energy Agency (IEA)

of Hurricane Katrina and Rita in 2005 (certainly not a geopolitical event), and separates the Venezuelan strike from the onset of the war in Iraq.

In IEA's list we find again six international conflicts, three domestic conflicts and one event which is not geopolitical in nature but rather an Act of God (the hurricanes).

Our analysis will cover these events and more in some detail, critically examining their impact and probability of repetition.

1. Geopolitical Threats to Oil Security

It is generally understood and accepted that geopolitical factors may negatively impact oil supplies. However, moving from this broad statement to a more precise definition and evaluation of the threat, which might offer a satisfactory basis for discussion of potential remedies and cost-benefit analysis of adopting the same, is a much bigger challenge.

We shall distinguish between resource nationalism as an ideology, which is widely believed to negatively affect oil exports, and political instability as a phenomenon that may lead to the same outcome.

1.1 Key Concepts and Definitions

In real life, the exact boundaries between resource nationalism, political instability, and conflict are sometimes blurred.

We shall include under resource nationalism all policies undertaken by the national governments of the producing country which restrict access to resources to a subset of potential players, or create separation between the domestic and international market, or directly impose quantitative limitations on production and exports. These policies may result in lower exports either indirectly or directly.

Political instability will encompass changes in policies that are the result of changes in the structure of power, i.e. in the government in place.

The concept of political instability deserves separate treatment because it aims at measuring the stability of policies in the presence of changes in government.

Political instability may be the outcome of constitutional processes – as it is normal in democracies – or extra-constitutional transitions, which we may group in the two main typologies of "coup d'état" and "revolution." The case of failed states, when central government authority collapses entirely and is substituted for by generalized armed violence, may be viewed as an extreme manifestation of political instability.

1.1.1 Resource Nationalism

The definition of resource nationalism, as given above, encompasses a wide variety of policies.

Access to resources may be forbidden absolutely, on environmental or strategic grounds (an example is US restrictions on offshore drilling); or limited, delayed or otherwise hindered by the opposition of the local population or authorities, on environmental or "fair share" grounds (an example of both issues being tar sands in Canada).

More frequently, access is restricted to specific categories of players. The latter are normally national oil companies, whether government or privately owned. In most producing countries, the national oil company enjoys privileged access, either through the total exclusion of foreign companies (e.g. Mexico, Kuwait) or by forcing the latter to enter into joint ventures with the national oil company, and in some cases mandating that the national oil companies own 50 percent or more of the equity. However, there are countries in which all national oil companies, including private companies, enjoy privileged access (this is the case of the Russian Federation, for example).

Secondly, access to resources may not be restricted to specific categories of players, but the development or pace of exploitation of resources may be constrained in order to conform to OPEC quota discipline or support OPEC action to manage the market – in the case of those countries that are not members of OPEC; or with a view to extending the productive life of the fields. Limits on production may be imposed on foreign companies even in cases where they enjoy equity access to oil resources, as contracts or regulations frequently impose on the operator the obligation of submitting a production plan and obtaining the approval of the relevant authorities.

Thirdly, restrictions may be imposed on exports, to benefit domestic consumers and industrial users. These restrictions may take the form of export taxes; limitations of physical access to export facilities (pipelines to reach terminals, access to loading terminals); preference for domestic refineries which, in turn, may be mandated to serve the domestic market at prices set below their international level; or simply, in the case of gas, refusal to invest in export infrastructure and projects. In other words, restrictions to exports may be the outcome of either actions or the failure to act.

All the above-listed policies allow for considerable variation and flexibility in implementation. Resource nationalism, therefore, is a phenomenon that should be viewed as having ups and downs, and involves adapting to circumstances.

Historically, access of international oil companies to resources has faced progressively more stringent restrictions. IOCs used to enjoy predominant access and control before 1970 but lost their position in the following decade. Changes since 1980 have not been as impressive as in the crucial decade of the 1970s.

In the 1990s and early 2000s it had been predicted by some that the pendulum would swing back, and international companies would be able to acquire much more direct control over reserves. This was linked to the expectation that Russia would open up and become fully accessible, and the toppling of the Saddam regime in Iraq would be instrumental in again opening the doors to that country. In fact, neither has happened, and if anything, we have witnessed a toughening of conditions for the IOCs.

Considering that four out of five countries holding the largest reserves (Saudi Arabia, Iran, Iraq and Kuwait – roughly half of global reserves) are almost entirely off limits, major shifts in the distribution will be possible only if the policies of one or more of these countries were to change.

In 2009, Iraq conducted two rounds of bidding, which led to the awarding of 10 service contracts (that is, contracts that do not offer the IOC the possibility of booking reserves) at conditions that are judged as extremely demanding for the companies involved. The future of these contracts is still clouded in uncertainty, but one thing is clear: for the foreseeable future, the IOCs will not have access to equity oil in Iraq.

The Kuwaiti government appears to have given in to opposition from the Parliament and renounced "Project Kuwait," which it had pursued for more than 15 years; but the domestic political situation may evolve and a shift in policy may occur.

Finally, Iran has sought greater involvement of the international oil companies for years and blames international sanctions for the difficulties it has encountered.

In short, resource nationalism may be viewed as rather normal behavior on the part of governments of oil-producing countries. It may have multiple manifestations and comes in degrees, rarely entirely excluding IOCs from access to resources. Resource nationalism is a manifestation of the fact that each producing country wishes to maximize its share of the rent and limit the companies' share of the same. It is a market relationship in which each side's bargaining strength shifts over time. It is a banality to say that more investment would go into finding and producing oil if governments renounced some of their share of the rent and allowed companies to get more of the same. In this sense, resource nationalism restricts oil production; but this is the outcome of producing countries protecting their interest, which is obviously their right to do.

Depletion Policies

Historically, we find instances in which governments of oil-producing countries conflicted with international oil companies because they felt the latter under-exploited the resources entrusted to them, and in some cases on the other hand, over-exploited them.

Iraq is a clear case of a long-standing conflict with the international oil companies due to various sources of tension, including that the Iraqi government felt that companies were sitting on its oil resources, without adequately exploiting them. In turn, companies were not willing to invest in Iraq because of persisting conflicts on issues related to taxation and control. The Iraqi nationalization of 1973 was motivated, among other things, by the desire to significantly expand production and exports. Accordingly, Iraqi oil production grew rapidly for the rest of the 1970s, until the war with Iran broke out and production was negatively affected.

In most contemporary cases, the international oil companies wish to maximize short-term production provided that good field management practices are followed – it is the local government that in some cases prefers to slow down exploitation and keep more of the oil in the ground.

Saudi Arabia is the main case in point. The Kingdom has enunciated a strategy of not exceeding a production level which it may confidently maintain for a period of at least 50 years: no profit-maximizing company would consider such an extended plateau, as the discounted value of oil to be produced 50 years from today is normally deemed very low.

According to some statements, Saudi Arabia believes that the maximum level of production defined in this way is 15 million b/d, including some use of currently non-proven reserves. More recently, King Abdullah of Saudi Arabia instructed the national oil company not to further increase capacity, but rather to keep resources for future generations: the impact of this is not entirely clear at the time of writing.

However, no other producing country has a similarly clear-cut and explicitly enunciated draw-down strategy. Most producing countries seek to increase their production and exports, while at the same time more or less respecting OPEC quotas

– but compliance with the latter is less than perfect.

Outside the Gulf Cooperation Council (GCC), practically all producing countries are concerned with maximizing their production and exports and adopt what they consider appropriate policies to this end. Some countries that at one stage had adopted a resource nationalist attitude later changed course and allowed international oil companies back in. Three notable cases in point are Venezuela, Algeria and Qatar. The Russian Federation may also be included in this list, if we consider the shift in policy that followed the collapse of the Soviet Union. Of these four cases of re-opening, only one has remained unaffected by further changes in policy - that is Qatar.

Conclusions on Resource Nationalism

In most cases, resource nationalism appears to be motivated by rent maximization. Hence, we see more restrictive policies adopted when prices are increasing, because the producing country's government feels that whatever arrangements are in place do not allow the country to obtain its "fair share"; and at the same time the government and/or the national oil company will enjoy larger financial resources and will feel that they can undertake whatever investment is needed on their own, without recourse to IOCs. Conversely, when oil prices are low, increasing export volumes will be more important and financial resources for investment will be scarcer: the contribution of IOCs is more attractive.

The range of attitudes depends primarily on structural factors rather than political or ideological inclinations. Some countries – primarily those endowed with larger reserves – find nationalist attitudes more attractive than others, while a large number of countries – notably those endowed with relatively smaller reserves – never seriously considered excluding IOCs. It may appear that some countries are prisoners of ideological limitations which they would like to shrug off but cannot (Mexico? Kuwait? Iran?). But then one should not underestimate the nationalist sentiment in domestic public opinion (Russia, Venezuela, Iraq, and Kuwait).

Looking towards the future, no fundamental shift is to be expected in the current pattern. Rather, there will be oscillations, with some countries opening up at times and closing off at other times, depending on circumstances such as price levels, availability of resources, need for expensive EOR technology and the like. At the same time, some countries will surely remain almost entirely closed, and others will continue to rely on IOCs, as they have done until now.

In the light of recent developments in Iraq, it is likely that this crucially important country will open its doors only marginally. IOCs will be allowed to operate on the basis of production sharing agreements in the Kurdish region in North Iraq; but elsewhere in the country they will be confined to service contracts. Now that several large service agreements have been concluded, Iraqi production may well increase rapidly. Much will depend on the implementation of these agreements and on the improvement in security conditions in the country.

1.1.2 Restrictions on Exports

Resource nationalism restricts access to resources to national players; restrictions on exports are policies through which exports of oil and gas are controlled even if access to resources is not limited and IOCs are allowed to invest and operate. Generally speaking, the existence of restrictions on exports will discourage IOCs from investing in the country.

Export Policies

In some cases, we see countries adopting policies that simply prohibit export of hydrocarbons. This is seen most frequently in the case of natural gas – in some cases also for specific petroleum products such as gasoline – as a move to protect domestic supplies.

Policies banning or restricting the export of natural gas are notable and more widespread than commonly realized. The rationale is very simple: natural gas is a resource which should be reserved to fuel national development. Countries producing both oil and gas frequently view oil as destined primarily for export, and gas as reserved for domestic consumption.

Taxation Policies

Export taxes are a tool not only to extract at least part of the rent generated by oil and gas production, but also to favor domestic consumers by creating a differential between domestic and international prices. When it comes to oil, an export tax is a very rudimentary form of taxation and, accordingly, is rarely used.

The most important and widely debated case of export taxes on crude oil exports is that of the Russia Federation. Export taxes on crude oil also exist in Argentina and Vietnam. China has had an export tax on offshore oil produced by foreign joint venture partners since 2006. Kazakhstan imposed an export tax on crude oil in 2003, but abolished it as of January 2009. The Russian export duty has been identified as a disincentive to expand production. Oil companies lack stimulus to increase production because of the high tax burden. Oil export duties are still a very important source of revenue for the Russian state treasury, providing for more than half the oil and gas revenue of the federal budget, and, therefore, about one-fifth of all budget revenues.

In the longer run, it is likely that export taxes and duties on crude oil will be substituted for by other, more effective and less distorting forms of taxation.

Exports may be restricted because the government pursues a market intervention strategy (whatever the target of the same) and modulates exported volumes in order to achieve certain price objectives.

The obvious case is collective action by OPEC to impose and modulate quotas. OPEC quotas are imposed on total production, not on exports – but in fact the determination of quota levels is primarily influenced by international market conditions and accumulation of stocks, and domestic requirements are added to whatever is believed to be the optimal volumes of crude oil to be added to the market.

Non-OPEC oil exporters may also place restrictions on exports in cases of severe weakness in oil prices: they are then "encouraged" to align themselves to OPEC practices either explicitly or implicitly.

Domestic Pricing Policies

It is very common for oil and gas producers – indeed, for a large number of developing countries – to enforce domestic prices which are lower than international prices.

The problem might not exist if international prices were more stable and increased only gradually. But the wide swings and price explosions as experienced in the first half of 2008 are difficult to pass on to domestic consumers in countries which export the vast majority of their oil and gas. As hydrocarbons are generally sold by government-owned entities, increasing domestic prices will shift purchasing power from the population to the government at a time when the latter is likely to be already flush with cash.

Obviously, artificially low domestic prices will tend to result in relatively higher demand, discouraging conservation and the efficient use of energy as well as the development of alternatives. All of the above are in prominent display in many developing countries, notably the oil producers.

The use of lower domestic prices as a tool for encouraging industrialization and economic diversification is, however, a separate matter and is quite more defensible than enforcing low prices to the final consumer. Offering low-cost inputs is a valid and effective industrial and development policy, and has yielded excellent results. The impact of this policy on global energy supplies is minimal, and concerns about security of supply do not offer a valid reason for criticism.

Conclusions on Restrictions on Exports

Our analysis has shown that restrictions on exports are widespread and take multiple forms. The problem is more acute for natural gas, but domestic demand may be favored over exports also in the case of oil and oil products. All forms of restrictions are, in a sense, a threat to security of supply, because they result in lower production and exports ceteris paribus. Depending on one's view of available resources and of the likelihood of supplies peaking because of the physical and technological impossibility of maintaining production, the fact that production is lower than might otherwise be the case shall be considered good or bad. Some view high oil and gas prices as a positive development, because they encourage savings and uptake of alternative sources of energy.

1.1.3 Political Instability

Political instability refers to government/regime change leading to changes in policy, whether brought about by constitutional or non constitutional means. It differs from conflict.

Historically, it is difficult to see any fundamental difference between constitutional and non constitutional changes in government when it comes to oil and gas export policies. In the vast majority of cases, neither category leads to significant changes in oil and gas policies. However, there are a certain number of notable exceptions, which belong to both categories of constitutional and non constitutional changes:

1. the appointment of Mohamed Mossadegh as Prime Minister in Iran
2. the coup d'état which led to his demise and the restoration of the power of the Shah
3. the collapse of the monarchy and the advent of General Qasim to power in Iraq
4. the collapse of the monarchy and the advent of Colonel Muammar Qaddafi in Libya
5. the Islamic Revolution in Iran
6. the collapse of the Soviet Union and the coming to power of Boris Yeltsin in Russia and other post-Soviet leaders in the key oil- and gas-producing former Soviet republics (Azerbaijan, Kazakhstan, Turkmenistan)
7. the election of Hugo Chavez in Venezuela
8. the election of Vladimir Putin in Russia
9. the election of Evo Morales in Bolivia
10. the collapse of the Saddam Hussein regime in Iraq

We believe that these 10 events include all major cases in which power shifts have led to major changes in oil and gas policies. Minor changes – adjustments to existing policies – occur more or less continuously, and are implemented by existing as well as new governments. Of the 10 cases listed above, four (cases #1, 7, 8 and 9) were constitutional changes, while the rest represent breaks in constitutional continuity, i.e. regime changes.

Of the 10 episodes, only two are considered major crises by the EIA, namely the Iranian nationalization of 1951 and the Iranian Revolution of 1978; only the latter is considered a major crisis by the IEA. Other events in the list have determined shifts in oil and gas policies but in the direction of increasing, rather than reducing, oil and gas supplies (the coup against Mossadegh, and possibly the collapse of the Soviet Union).

In all cases, further shifts in power and consequent shifts in oil and gas policies cannot be excluded. In Russia, a swing of the pendulum back to greater involvement of the IOCs is possible, if the national companies fail to at least maintain oil and gas production levels in the face of mounting technical difficulties. A revision of policies may or may not be associated with changes in power. In the Central Asian and Caucasian republics a shift in the opposite direction is possible because of the opaque nature of many deals and outcomes that are not beyond criticism. However, it is unlikely that any change in power may lead to dramatic changes in oil and gas policies, because the countries are objectively in a difficult position and have limited alternative options.

Patrimonial regimes continue to rule some of the key oil- and gas-producing countries; they have weathered well the challenges of the last decades and displayed singular durability. We believe that in all likelihood these regimes will remain very stable because they have very strong roots in society, and control of the oil rent affords to them exceptionally strong tools for dealing with society's aspirations.

By all evidence, the age of frequently-repeated military coups belongs to the past and is an increasingly distant memory.

However, having said that, the possibility of regime changes in some of the major oil and gas producers in the Gulf cannot be excluded. What might happen to oil and gas policies in that case?

As discussed, Saudi Arabia and Kuwait remain essentially closed to IOC investment, while Abu Dhabi is open but the government closely controls the activities of foreign oil companies. Nationalization is theoretically possible in Abu Dhabi and Qatar, not in Saudi Arabia or Kuwait as there are no foreign companies that may be nationalized. More likely, attention will focus on export levels, and a more conservationist approach may emerge. This would be in line with the experience of Iran at the time of the revolution, and with the experiences of Venezuela and Bolivia.

Political change may be instrumental in provoking shifts in that direction, unless sufficient incentives exist in the global economic environment to discourage this tendency. Policy shifts in this direction are more likely to be associated with changes in power, including by constitutional means, and are frequently associated with the electoral success of populist leaders, but also may very well be associated with the passage of power from one to another member of a ruling family.

The experience of Iraq since 2003 is extremely telling of prevailing trends. Notwithstanding the collapse of the Saddam Hussein regime and the occupation of the country by foreign forces, followed by the progressive empowerment of a new constitutional order amidst multiple contradictions and uncertainties, we have not witnessed the unrestrained opening of the hydrocarbons sector and the rapid build-up of production and exports that was touted by some on the eve of the coalition's intervention. However, the situation of the Kurdish province of Iraq differs from the rest because of the profoundly different political history and the long-standing experience of autonomy from Baghdad.

Conclusions and Indications for Scenario-building

The analysis in this first section has shown that there is no easy and immediate connection between resource nationalism or political instability and global supply of oil and gas. This is definitely not because political developments are irrelevant in influencing oil and gas supplies, but because this influence is highly variable and unpredictable.

Political factors act as one of the elements which prevent the oil and gas upstream industry from behaving in a perfectly economic-rational way, optimizing supply at all times.

Political circumstances may influence the gap between maximum optimal production and what is actually achieved, and let it widen or narrow down. The existence of conditions of financial stability and growth is crucially important in determining the attitude of producing countries towards the desirable level of production and exports.

Similarly, expectations about the future level of oil and gas prices also influence political attitudes towards oil and gas production and exports. If the market expects that supply will grow progressively scarcer in the face of growing demand, then the incentive to slow down production and exports is increased. The adoption of aggressive policies aimed at decarbonisation and energy efficiency may have an ambivalent effect: there may be a negative announcement effect, because producers will fear demand destruction and invest less in expanding or maintaining capacity; and a positive market effect, when demand is effectively reduced, ceteris paribus. Hence the suggestion might be not to entertain policy objectives which cannot realistically be reached and emphasise cooperation and pragmatism rather than confrontation and maximalism.

It has been seen that political instability and resource nationalism have been rarely been associated with acute supply crises or shortfalls. Their effect is rather gradual and normally compensated by action in other parts of the system. Today, the system appears quite flexible and capable of withstanding even important shocks, primarily thanks to excess capacity available in Saudi Arabia. But if Saudi Arabia itself were to experience severe political crises, problems may arise even today. For the longer term, the danger that capacity additions may fall systematically short of demand increases exists and would entail a progressive fragilisation of the system.

2. Domestic/International Conflicts and Terrorist Activities

We shall distinguish between three main categories of armed conflict: 1) "classic" interstate warfare, which is fought primarily by regular armies; 2) civil wars, in which armed forces from opposing sides within the same country engage in violent encounters; and 3) terrorism/banditry.

Interstate wars involve the armed forces of two or more states, generally fighting for control of disputed territory, or engaging in occupation of enemy territory beyond what is contested in order to force the enemy's surrender. It involves the use of the states' armed forces: they are sometimes officially declared by the belligerents and have a clearly identifiable end in a peace treaty or at least a ceasefire of indefinite duration.

Civil war is distinguished from interstate war because it is fought between forces belonging to the same state and fighting either for redefinition of that state (e.g. secession of a province) or for control of power in the state as a whole. The distinguishing feature of a civil war is that either side (or all sides, if there are more than two) controls a portion of the national territory.

Terrorist activities are distinguished from a civil war because one side has no permanent and continuous control of a portion of the national territory. The distinction between resistance, terrorism, and banditry is one of motivations and rights, not one of observed behavior.

We shall in the rest of this paper refer to the technically preferable terminology of "violent non-state actors" to encompass all forms of violence on the part of non-state actors who do not continuously control a portion of the state territory.

As far as our discussion is concerned, this distinction is important because in a civil war the state may lose access to some oil resources, while in the case of violent non-state action, the state may not be able to avoid damage to oil installations, but maintains access to the same.

2.1 Trends in Armed Conflict

The frequency, duration and scope of interstate conflict have dramatically diminished. Interstate war in its classic form has today almost completely disappeared in all parts of the world, except the Middle East.

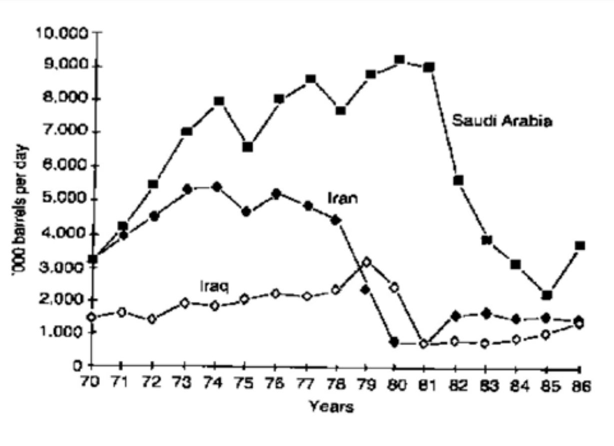
In contrast, civil war and the use of violence on the part of non-state actors have continued. A majority of large-scale conflict which solicited major power intervention in the past 50-60 years originated as civil wars: Korea, Vietnam/Laos/Cambodia, former Yugoslavia, Afghanistan. Other civil wars did not solicit direct major power intervention but have had significant impact nevertheless: Nigeria (Biafra), Angola, Zaire, Congo (Brazzaville), Sudan, Somalia, Lebanon, Yemen. We may also regard the intervention of the US-led coalition in Iraq as outside intervention in a civil war (the Baghdad government had in fact lost control over Northern Iraq; nevertheless, this is a sui generis case, because the opposition to Saddam was not able to operate in the rest of the country).

Further detailed analysis would show that a majority of wars are fought over relatively short periods of time (the major recent exception being the Iraq-Iran war, which turned into something resembling the First World War in Europe) and then resolved either by the decisive military victory of one side (where military victory does not necessarily translate into political victory) or by forceful international pressure and intervention.

We also see that domestic conflicts, sometimes leading to outside armed intervention, are primarily linked to complex historical transitions that leave unresolved issues behind. We can thus cite the process of decolonisation (in the Near East; in South and Southeast Asia; in Africa) as being a primary cause or occasion for violent domestic conflict.

In most cases, a period of acute instability is followed by consolidation of existing structures and eventual progressive decline of the use of violence. This process may be said to have concluded in Southeast Asia (where it has been extraordinarily costly in terms of human casualties), and conflicts have been essentially frozen elsewhere (between India and Pakistan; and in the Balkans) but a clear trend towards pacification is not visible elsewhere, notably in Sub-Saharan Africa. In the Near East, the main conflict (between Israel and its Arab neighbors) has progressively been reduced in scope, following the peace treaties signed with Egypt and Jordan, and the freezing of war with Syria. Lebanon still constitutes a problem area; otherwise, the conflict has now become a purely Israeli-Palestinian affair, into which Arab neighbors are not willing to be drawn and intervene militarily. The future of Iraq and Afghanistan also remains

Figure 3: Crude Oil Exports of Iran, Iraq and Saudi Arabia, 1970 to 86



Source: OPEC Annual Statistical Bulletin, 1987

uncertain, and the intentions of Iran are not clear – claims over Bahrain keep resurfacing from time to time, although not in the form of official policy.

The collapse of the Soviet Union has been another occasion for violent conflict; tensions have cooled but not disappeared. Notably, the Caucasus remains an area rife with conflict, with antagonism/hostility persisting between Azerbaijan and Armenia, Georgia and Russia, and with secessionist movements in some Russian republics. At the same time, there has been some improvement in the troubled relationship between Turkey and Armenia following the visit of the Turkish President Abdullah Gul to Armenia in September 2008.

2.2 Historical Experience of Oil Supply Interruptions due to Conflict

The lists of major oil supplies disruptions published by the EIA and the IEA concur on six armed conflict events which caused major disruptions; these are:

1. The Suez Crisis
2. The Six-day war
3. The Yom Kippur war
4. The Iraq-Iran war
5. The Iraqi invasion of Kuwait
6. The US-led Coalition's intervention in Iraq.

Of these, the first two (Suez crisis and the Six-day war) affected global oil supplies primarily because the Suez canal was closed – for a short period in the first case and a much longer period in the second.

In the following pages, we discuss the remaining episodes.

The Iraq-Iran War (First Gulf War)

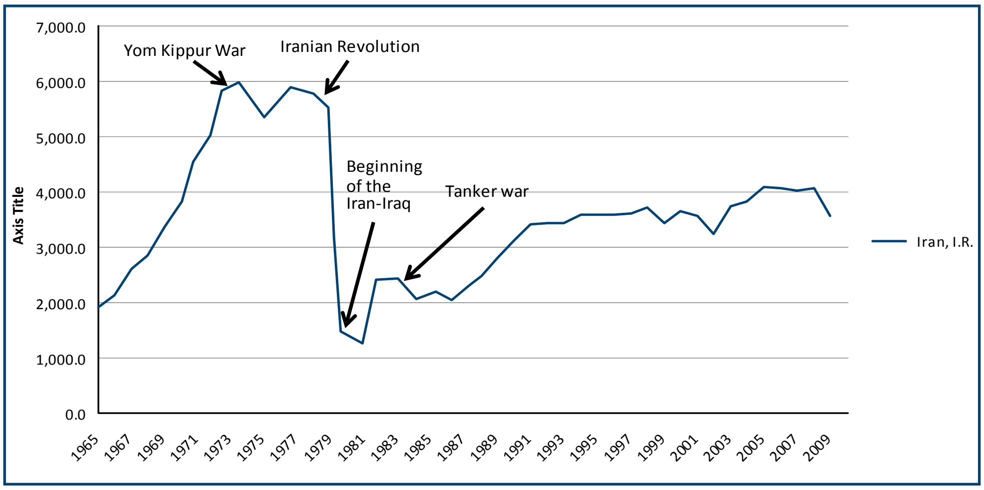
The Iraq-Iran war is especially important for our analysis because it is the only historical example of an interstate war between two major Gulf producers, which was bitterly fought over an extended period of time (eight years) with very high cost in terms of human life and surprisingly limited intervention on the part of outside powers. It was, in other words, the "perfect storm" or "nightmare scenario."

Given the importance of oil as the economic and financial basis for conducting the war, it is hardly surprising that the two countries repeatedly attempted to interrupt each other's oil exports. The remarkable fact is that both failed: exports continued at levels that, in the light of the decline in international demand and OPEC's attempts at rationing production, may be considered 'normal'. All three major OPEC producers experienced very substantial decline in their production levels in response to the decline in OPEC's overall international oil market share, rather than because of the war. If we consider the period 1970-78, we find that Iran exported on average 4.625 million barrels per day (b/d), Iraq 1.908 million and Saudi Arabia 6.525 million. The impact of the war appears to have been very significant only in 1980-81, when both Iranian and Iraqi exports were very low, while Saudi Arabia was pumping at an extraordinarily high level.

In the first days of the war Iran attacked the pipelines through which Iraq exported oil to the Mediterranean across Syria and Turkey. But by the end of November 1980, Iraq had resumed exports via Turkey at an estimated level of 400,000 b/d. At the same time, Iraq also attacked Iranian export installations and caused considerable disarray, but within a month Iran was already exporting again, to the tune of 3-400,000 b/d.

Overall, the experience of the war suggests that overland oil transportation via pipelines is more resilient to attacks than maritime outlets and sea transportation. While the Iranian oil terminal at Kharg island was able to continue operations (albeit far below its theoretical maximum capacity), its well-advertised air defense system could not prevent substantial damage. In fact, after the Iraq-Iran war it became clear that – short of physically occupying the wells – there is little an attacker can do to deny permanently an outlet to an enemy's oil exports.

Figure 4: Impact of Geopolitical Events on Iranian Oil Production 1965-2007



Source: OPEC

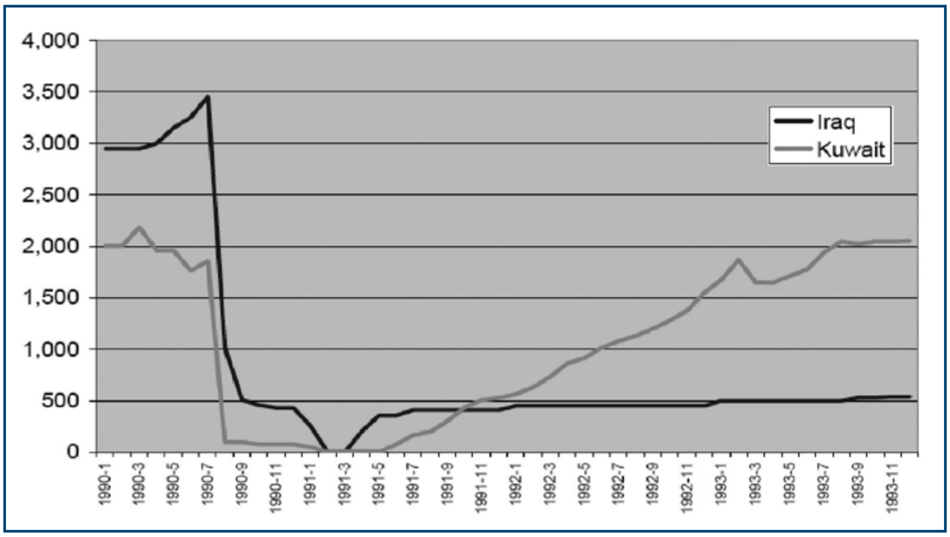
To the very end, the Iraq-Iran war remained one between Iran and Iraq and did not turn into an arena for superpower rivalry. One explanation is that the conflict occurred at a time when oil markets were awash with crude supplies, and there never was a serious threat of shortage: it was made clear early that the supply shortfall could be made up from other sources. As events unfolded, the resilience of the oil export system became increasingly manifest. Thus, throughout the war there never was a time when the West saw its vital interest directly and immediately threatened.

The Iraqi Invasion of Kuwait (Second Gulf War)

The invasion provoked the collapse of oil production in both Iraq and Kuwait, because of the immediate international reaction and the boycott of exports of both countries. Otherwise, the invasion per se did little damage to the oil installations. However, when the international coalition formed to liberate Iraq launched its offensive, the Iraqi troops set on fire more than 600 Kuwaiti oil wells: thus the major damage was done not by the hostilities per se, but by deliberate sabotage on the part of the withdrawing Iraqi troops.

The war was important for its multiple lessons. Firstly, it made clear that the international community and the major Western powers (the two converged on this occasion) would not tolerate a major revision of the region's political map.

Figure 5: Oil Production of Iraq and Kuwait 1990-93



Source: Data BP Statistical Review of World Energy, various years

Secondly, the war confirmed that when modern military forces are involved and advanced weaponry is available, the conflict is likely to be short and have a clear winner. Thirdly, it was shown that the only way extensive damage can be inflicted on oil installations – especially upstream oil installations – is if there is a physical military presence on the ground.

The US-led Coalition Intervention for Regime Change in Iraq (Third Gulf War)

Sanctions remained in place against the Saddam Hussein regime throughout the period from the withdrawal of Iraqi troops from Kuwait to the US-led invasion of Iraq in 2003. Sanctions did have an impact on the availability of crude oil to the world, and there is little doubt that Iraq would have produced more than it did, had international oil companies been allowed to sign the contracts that were on offer during the 1990s. Arguably, sanctions imposed by importers have had very significant impact on oil production, much more significant than most conflicts, terrorism or "resource nationalism."

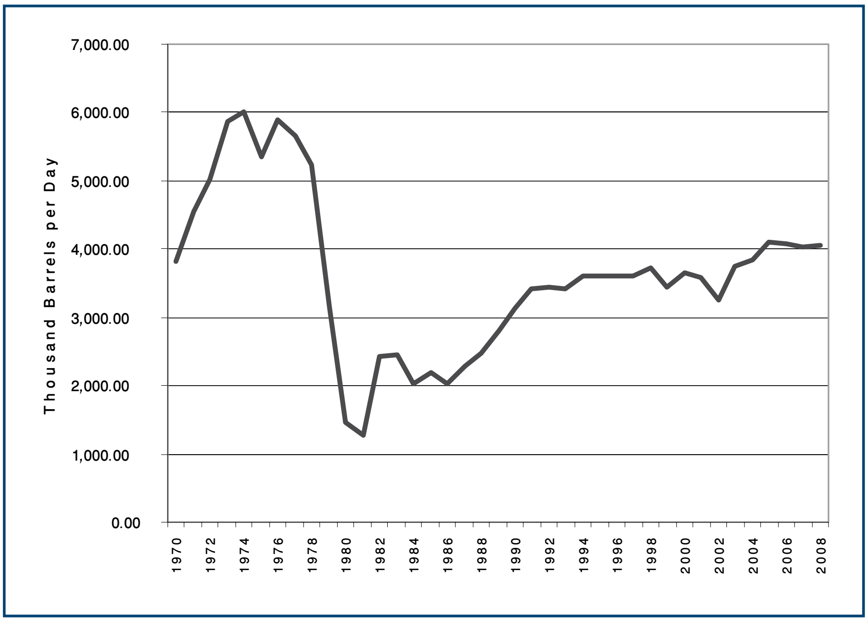
The military operation to topple the regime of Saddam Hussein began on March 20, 2003, and effectively finished on April 15. On May 1, President Bush addressed the nation from the deck of the USS Abraham Lincoln claiming "mission accomplished." The next phase, commonly dubbed the "insurgency," was technically a widespread wave of violent action on the part of non-state actors, not entirely coordinated in a single opposition force. This led to extensive losses of human life but also widespread sabotage of oil installations.

Terrorism and Oil Installations in Iraq

Iraq's oil sector was a target of insurgent activity almost since the beginning of the US occupation in April 2003. The first recorded attack took place in mid-June 2003, merely two months after the occupation of Baghdad. The oil and gas pipeline network is the most vulnerable of Iraq's oil infrastructure and was the main target of attacks; over 280 attacks or sabotage operations were carried out between mid-2003 and 2007. Attacks were aimed at the destruction or disabling of the pipeline network, as well as at preventing the repair or restoration of the network. In the period 2003-2007, almost 90 attacks were carried out on oil sector personnel. As a result, Iraq's oil sector lost between 10-15 percent of its work force.

Attacks on the Iraq-Turkish pipeline rendered it non operational for a long period. Every day that this pipeline was not operational, Iraq's economy was losing approximately $7 million. Three suicide boats attacked the Basra offshore oil export terminal. Though the terrorists failed to damage the facility, this attack alone cost the country some $40 million in lost revenue. If we consider monthly oil production data and the maximum excursion from the lowest point (January 2007) to the highest recorded production (December 2007), then we should say that security disturbances cost Iraq fully 1 million b/d.

Figure 6: Iran Crude Oil Production



Source: BP Statistical Review of World Energy, various years

War, Sanctions and Iranian Petroleum Production

Estimating the effects of the war and sanctions on Iranian production is much more complicated: the Iran-Iraq war ended in 1998, and the country has been living in peace since (peace, of course, is different from entertaining good relations with the international community). Nevertheless, Iranian oil production has not recovered to anywhere near the level that it reached in 1972 and 1975. The initial decline was certainly due to the Revolution rather than the war, and was to some extent deliberate. The painful climb back to 4 mb/d may be attributed to the combination of external sanctions and internal infighting, which have seriously hindered the potential for attracting outside investment. In short, the poor outcome is largely due to Iranians themselves, and is also to a large extent deliberate, the fruit of choice rather than necessity. Call it resource nationalism or simply sectarianism—war is by now too distant to offer a credible justification.

Other Examples of Oil Supply Disruptions Caused by War

Nigeria

The case of Nigeria offers a good example of the impact of civil war, and then continuing strife because of serious unresolved domestic political and institutional issues, on oil production and supply.

The Biafra War

The war which followed the declaration of independence of Biafra from Nigeria lasted three years, from 1967 to 1970, when the south-eastern province of Biafra wanted to break apart from the country. Oil installations were affected, and the civil war had consequences on Nigerian production. In the first year of the civil war (1967), average daily production declined about 24 percent, from 417,000 to 319,000 b/d. The decline continued the following year, when Nigerian production reached a minimum level of 141,000 b/d. However, in the third year of the war, production jumped and surpassed the level recorded before the war. The war ended only two years later.

Ethnic Conflict in the Niger Delta

The end of the Biafra civil war did not solve the root causes of the problem. Ethnic tensions have continued in the region, fuelled by a sense of grievance of the local populations, who feel deprived of their "fair share" of the oil revenue. In 2003, an estimated 800,000 bpd was shut-in due to civil unrest. Since then the situation has deteriorated. In June 2008, an attack on Shell's largest producing field, Bonga, was carried out, despite being more than 100 km offshore. Bonga is responsible for 10 percent of Nigerian output, about 200,000 bpd. Nigeria risks losing a third of its oil output by 2015, unless it finds ways to boost investment in joint ventures with foreign energy companies.2 Although the Movement for the Emancipation of the Niger Delta (MEND) accepted a ceasefire in July 2009, the situation remains unclear and attacks are still to be feared.

Angola

The Angolan civil war lasted 27 years, from 1975 to 2002. It was at the same time a war for the control of power in Angola proper and a war against the secession of the Cabinda enclave, where onshore oil production is located. The civil war has had limited impact on the progress of Angolan oil production. The production stagnated for a period roughly coinciding with the first 10 years of the civil war (1974-83). It is reasonable to conclude that in the absence of civil war Angolan production might have expanded earlier, but then it did increase very rapidly even during the last 17 years of civil war.

Sudan

Sudan has known civil war almost without interruption since its independence, and still does today. Civil war has significantly hindered exploration and development of the Sudanese oil resources. Today, the major producing company in the country is China's CNPC. The region where oil was originally discovered lies at the border between North and South Sudan, making the situation even more difficult. However, exploration is currently underway throughout the country, including in parts of Darfur, and some observers attribute the second civil war and the current war in Darfur to the prospect of oil income.

The *Oil and Gas Journal* lifted its estimate of Sudan's reserves from 563 million barrels in 2006 to 5 billion barrels in 2007. In the case of Sudan, the civil war prevented oil exports and revenue, creating conditions whereby the two sides were encouraged to reach a compromise.

Algeria

During the period of acute political violence that lasted from January 1992 to about 2002, attacks were overwhelmingly directed against human targets rather than economic installations. Very few attacks were recorded against oil and gas installations, in part because of their location in the desert, which makes them more easily defensible.

The lowest point was reached in 1987: thereafter, Algeria began to open its doors again to international oil companies, and production increased until 1991. The period of political violence (1992-2002) coincided with a bumpy plateau in Algerian production, which does not contradict the hypothesis that the conflict did constrain production growth, even if no major attacks were launched against oil and gas installations. Surely, the jump in production between 2002 and 2003 appears to indicate that the improvement of the situation allowed better use of existing resources.

Conclusions on Historical Experience of Oil Supply Interruptions Due to Armed Conflict

Oil and gas installations appear to be much more resilient to armed conflict than is normally acknowledged. Major damage is inflicted only in cases in which hostilities take place in the immediate vicinity of the installation (initial phase of the Iraq-Iran war, initial phase of the Biafra war, Sudanese civil war), or one side has control of the installations and chooses to sabotage them (Iraqi troops in Kuwait, MEND in Nigeria). But this is rare. Moreover, interstate wars are a low-probability event.

In contrast, civil wars' frequency has not diminished at the global level. Historically, civil wars have caused limited damage to existing installations, but they have hindered the desired investment in new development and attainment of target production levels.

Cases in which violent action on the part of non-state actors has inflicted significant damage to existing installations include the "insurgency" phase in Iraq and MEND in Nigeria. In both cases, the relevant non-state actor was based in the same territory as the oil installations, close to population centers which the government could not control well. If oil installations are in remote or uninhabited locations – as is the case in Algeria or Angola and many other countries including Saudi Arabia – then the cost-benefit balance of attacking oil installations is considerably worse for the non-state actor.

However, it is very obvious that government's inability to overcome or reabsorb violent opposition discourages international oil company investment even if the violence does not affect the vicinity of oil and gas installations; but if the expected return is large enough, projects will be undertaken nevertheless. The intensity of phenomena or the extent of the discrepancy between what is achieved and what would be optimal varies over time, justifying the need for reserve capacity and strategic stocks. But this need should not be measured against the theoretical optimum: it should be measured against the average that is normally achievable.

3. Scenarios of Future Conflict and Their Potential Implications for Oil Supplies

3.1 The Middle East

The discussion above clearly indicates that doomsday scenarios are not justified in the light of historical experience. An interstate war involving all major oil producers in the Gulf and provoking the disappearance of all Gulf oil from the market is simply not on the cards.

All interstate war episodes in the Gulf since 1980 have been linked to Iraqi action and the regime of Saddam Hussein. All other Gulf nations have demonstrated a strong inclination towards avoiding conflict

This is true also for the Islamic Republic of Iran, which has used proxies to engage in terrorist or other violent attacks abroad, but has refrained from engaging its own regular forces in any regional conflict. The war with Iraq was initiated by the latter, and more recently, Iran has avoided direct intervention in Afghanistan or Iraq.

The GCC member countries have never resorted to armed force – except Saudi Arabia in the context of the second Gulf war for the liberation of Kuwait. The GCC itself is primarily a pact of mutual assistance to maintain existing regimes in place. Territorial disputes and other sources of tension between GCC member countries exist, but they are very unlikely to ever lead to armed conflict.

Various Iranian political figures have claimed Iranian rights over Bahrain at various points in time – although this position has never been officially supported by the Iranian government. Considering that Bahrain hosts the headquarters of the US Fifth Fleet, which patrols the Gulf, and the fact that Iranian intervention would have to come from across the sea, any scenario of Iran threatening Bahrain beyond words does not appear very plausible. In any case, Bahrain is not a major oil producer.

A scenario envisaging Iranian intervention in Saudi Arabia is even less plausible. Attacks against oil facilities by aircraft are also unlikely because of superior Saudi control of the air space. In any case, such attacks are unlikely to be very effective, as the experience of the Iraq-Iran war has demonstrated, and would invite immediate retribution. Attacks with the use of missiles may be more difficult to intercept, but then they are likely to be inaccurate and would also invite immediate retribution.

Notwithstanding the very high level of expenditure on modern weapons and on the military in all Gulf States (or possibly because of it), it is very difficult to attribute significant probability to any scenario of interstate conflict between any two of the Gulf States. The worst that could be envisaged would be reciprocal air and missile attacks between Iran and Saudi Arabia, which may result in a shortfall of oil supplies to the market of the same order as during the Iranian revolution or the Iraqi invasion of Kuwait (about 5 million b/d). However, such a crisis would certainly be of short duration and would be followed by quick recovery.

This evaluation would not be substantially affected by Iran acquiring nuclear weapons. Using a nuclear weapon against even a critical oil installation would expose the country to very serious retaliation in exchange for very dubious benefit.

In contrast to the low probability of interstate conflict, intra-state conflict is a serious and imminent danger.

This remains true especially in the case of Iraq, where it is not at all clear that the country can survive as a unitary state and avoid bloody civil war(s). The status of the Kurdish provinces to the North remains highly contentious, and sectarian tensions between Sunni and Shi'a in the rest of the country are far from resolved. Continuation of domestic conflict and political uncertainty would obviously discourage needed IOC investment and further delay the development of Iraqi oil and gas resources. Considering the importance of Iraqi reserves, this is probably the single most important "threat" to European oil and gas supplies, subtracting a steady flow of the order of at least 4 million b/d, if not more.

Domestic conflict can certainly not be ruled out in the rest of the Gulf. The internal opposition to the Islamic Republic has become very apparent following the presidential election in June 2009, and will not evaporate. Tensions exist in all other Gulf countries, but until now regimes have proven resilient and have combined repression with accommodation in an effective blend, which greatly reduces the probability of any regime change scenario.

The Iranian government is also using repression to contain the wave of discontent, but it not clear if it will be successful in recovering broader support of its people and maintaining its legitimacy. Indeed, the one country besides Iraq in which domestic conflict may lead to serious interference with oil development is Iran – although this is more likely to take the shape of strikes or non-cooperation in the oil industry than of violent conflict or sabotage.

Iran may also interfere with the shipping of oil in the Gulf and through the Strait of Hormuz. It can be anticipated that any such action would be effective only in the very short run and would solicit a reaction on the part of regional and international forces stationed in the Gulf.

Of course, this discussion is based on the assumption that the main Western powers will remain actively engaged in Gulf security. If the United States and European forces currently present in the Gulf were to be withdrawn from the region, the strategic calculation, especially of Iran, might change. However, there is little reason why the US and European states should withdraw their presence from a region of such obvious importance to them.

3.2 The Rest of the World

Potential for interstate conflict still exists in several regions of the world, but some of the major cases are for countries that are not oil or gas producers (India/Pakistan, successors of former Yugoslavia) and, therefore, would have little impact on oil and gas production, besides having low probability.

Concluding Considerations on Oil Production and the Threat of Armed Conflicts

Evidence presented in this section and the discussion of several individual conflicts and scenarios for the future point to the conclusion that the global oil and gas supply system may be much less vulnerable to conflict than is commonly assumed.

The world has become a less conflict-prone place, and there is no strong reason to assume that this trend might be reversed in the coming two to three decades. Numerous domestic conflicts continue to plague certain regions, notably Sub-Saharan Africa and the Middle East, sometimes attracting armed foreign interference. However, it is difficult to propose scenarios that would have an impact on oil supplies bigger than what the world has already experienced and rather brilliantly dealt with.

However, these conclusions do not justify complacency. Supply disruptions of an order comparable to those experienced in the past are possible, and the ingredients which allowed for successful dealing with the situation in the past should be maintained.

The main tool to cope with supply disruptions in the past has been the unused production capacity of major producers, notably Saudi Arabia. This remains a cornerstone of global oil security. Strategic stocks have rarely been used, but have an important deterrent effect and may turn out to be especially useful in case of a more severe crisis of short duration.

4. Restrictions of Passage, Accidents and Oil Transportation Norms

The logistic aspects are frequently mentioned as a source of uncertainty, generally as part of a long list of other potentially disturbing factors. In this section, we shall focus on seaborne transportation of oil and oil products and consider how oil maritime transportation logistics may affect oil supply security.

There are three different dimensions to this question:

1. restrictions of passage, meaning wilful interference with the freedom of navigation on the part of riparian or other actors, including both state and non-state actors
2. accidents – involving one or more tankers and entailing environmental or other damages which may lead to the temporary closure of international waterways
3. oil transportation norms, that is rules governing navigation and passage through specific waterways.

A large proportion of global oil traffic is seaborne. Approximately 50 percent of globally produced oil and a higher percentage of internationally traded oil is transported by sea.

4.1 Oil Choke Points

The EC Green Paper on Energy Network Assessment[3] has the following definition of choke points:

"Chokepoints are narrow channels used for transit of large volumes of international sea trade including oil. The concerns related to chokepoints can be different: geopolitical in the case of transit through potentially unstable areas, environmental and in particular in relation to damage from an accident, economic if transit through a chokepoint requires long waiting times, security in connection to possible terrorist attack etc...

Chokepoints therefore represent critical bottlenecks in the energy transport network since they transit high volumes of crude and products and the impact of interruptions of transit through them would affect severely the global oil market."

Table 1: List of Choke Points

Choke Points	EIA	EC Green Paper	IEA
Hormuz	X	X	X
Malacca	X	X	X
Bab el Mandab	X	X	X
Panama Canal and Pipeline	X	X	
Suez Canal and Sumed pipeline	X	X	X
Turkish Straits	X	X	
Baltic Sea		X	

These passages are deemed especially important for global oil traffic. The International Energy Agency has estimated that the share of global oil consumption that transits through Hormuz might increase from 21 percent in 2004 to 28 percent in 2030, while the importance of the Strait of Malacca might be only marginally less (close to 24 percent in 2030).

The Gulf Countries and the Strait of Hormuz

The concentration of oil reserves and production in Gulf riparian countries inevitably inflates the volume of internationally traded oil which originates in the Gulf and must transit through the Strait of Hormuz.

The Strait of Hormuz is 21 nautical miles wide at its narrowest point, measured from Larak Island (Iran) to Great Quoin (Oman). Sovereignty over the strait is divided between Iran and Oman (the Musandam peninsula which defines the strait belongs to the latter).

The obvious threat to freedom of passage through the strait comes from Iran – no one seriously considers the possibility that Oman might wish to impede passage. The potential threat of closure from Iran has been evaluated in detail by C. Talmadge.[4] The author argues that it is not in the interest of Iran to close the strait as an offensive first move, as this would damage Iran itself and would certainly provoke retribution from the international community. However, "If the United States or Israel attacked Iran, the restraint that previously characterized Iranian behaviour in the strait might evaporate."

Indeed, in 2006 Iran's supreme leader, Ayatollah Ali Khamenei, cautioned that although Iran would not be "the initiator of war," but if the United States punished or attacked Iran, then "definitely the shipment of energy from this region will be seriously jeopardized." More recently, statements by President Mahmoud Ahmadinejad and other qualified Iranian sources have been rather on the cautious side.

The main conclusion of Talmadge's very detailed analysis is that "the notion that Iran could truly blockade the strait is wrong — but so too is the notion that U.S. operations in response to any Iranian action in the area would be short and simple." The key question is not whether Iran can sink dozens of oil tankers, which would be difficult. Tankers are resilient targets.

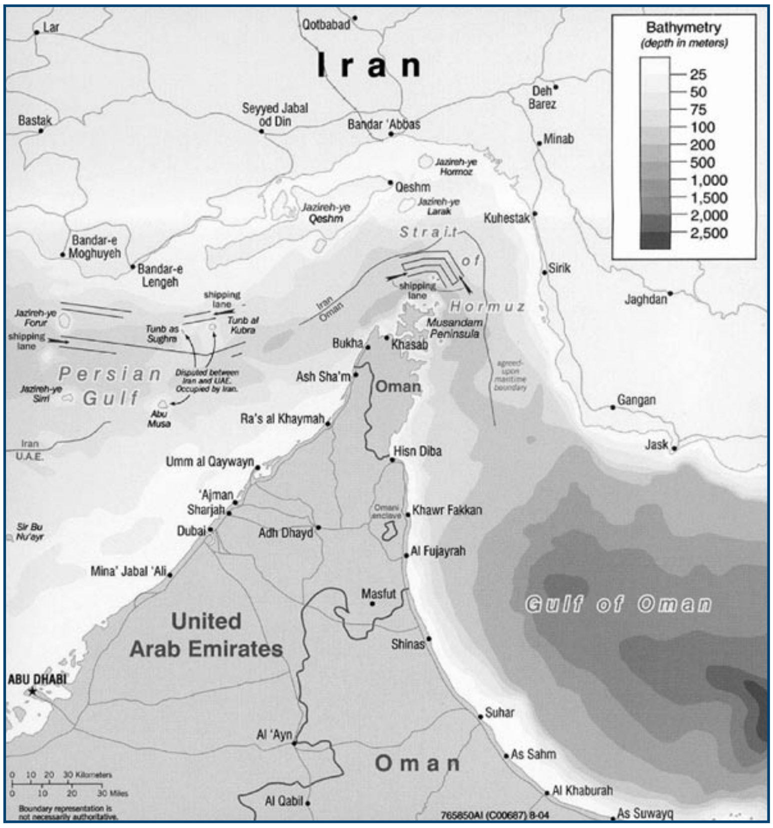
The question is whether Iran can harass shipping enough to prompt U.S. intervention in defense of the sealanes.

Therefore, a threat of closure of the strait, even if partial and/or limited in time to a period of several weeks is possible. "The United States' ultimate military superiority vis-à-vis Iran is without question, and eventually the United States would prevail in any confrontation. Nevertheless, mine warfare is within Iran's capabilities, and Iran possesses the anti-ship cruise missiles and air defence needed to make U.S. MCM operations even more difficult and time-consuming than they normally are (...). Most important, Iran does not have to seal the strait entirely to provoke U.S. intervention, and once that intervention begins, the potential for further military escalation is high (...). Either way, a significant and sustained increase in the price of oil would seem likely."[5]

The Joint Economic Committee of the US Congress published a study on "The Strait of Hormuz and the Threat of an Oil Shock." Rather than discussing the potential for closure of the strait subsequent to military action on the part of Iran, this study assumes that this is possible and investigates the potential economic impact of such a closure. Its key conclusions are:

"A closure of the Strait of Hormuz has the potential to reduce the flow of oil by far more than any previous disruption, both in absolute and percentage terms. Of the 85 million barrels the world consumes each day, 20 percent passes through the Strait of Hormuz. By comparison, the Arab oil embargo of 1973, at its peak, resulted in a gross supply loss of 5 mbd, representing 9 percent of world oil consumption (which has increased by 28 mbd since the embargo). The cumulative oil supply loss from a Strait closure could reach the total amount of oil lost during previous oil shocks in 17 to 37 days. Nevertheless, the OECD countries have enough oil in primary inventory to last them more than eight months, should Persian Gulf oil cease to flow." [6]

Figure 7: Strait of Hormuz



In this context, it is important to underline the potential role of pipelines to allow export of Gulf oil from terminals that are outside of the Gulf and do not require transit through Hormuz.

Of the five major Gulf oil exporters, three (Iran, Saudi Arabia and the UAE) have ports outside of the Gulf: Iran and the UAE on the Indian Ocean, outside of Hormuz; and Saudi Arabia on the Red Sea. Indeed, Saudi Arabia has a pipeline (known as the Petroline) with a capacity of 5 mb/d running from the Eastern province, where the oil is produced, to the Red Sea port of Yanbu, and it has been exporting crude oil and products from there since more than 20 years.[7]

Iraq does not have a maritime outlet outside of the Gulf, and indeed even its outlet on the Gulf is insufficient and cannot accommodate very large crude carriers. For this reason, it has developed over the years several alternatives, notably:

- A pipeline running from the fields in Northern Iraq across Turkey to the Mediterranean port of Ceyhan
- A pipeline running from the fields in Northern Iraq across Syria to the Mediterranean port of Banias
- A pipeline from the fields in Southern Iraq across Saudi Arabia to the Red Sea port of Yanbu' (known as IPSA)

The operations of all of the above have been disrupted by political and/or military interference at various times. Currently, only the pipeline to Ceyhan through Turkey is in operation, albeit at a low level (900,000 b/d currently versus an original design capacity of 1.6 million b/d).

In the end, Kuwait is the only major Gulf oil exporter which at present has absolutely no alternative but to ship oil through the Strait of Hormuz.

In conclusion, a threat to freedom of navigation through the Strait of Hormuz is a scenario that cannot entirely be discarded, but should be nuanced. There is universal consensus on the conclusion that, as long as a credible commitment on the part of the US to keep the strait open exists, its closure can only be temporary. In all likelihood, it would also be partial. In any case, mitigation measures are of the utmost importance – to react to a possible emergency and even more to prevent an emergency by reducing the expected benefit of closing the strait. Mitigation measures may be of a general kind, such as strategic stocks, or specific: among the latter we should in particular mention oil pipelines to loading terminals outside of the Gulf, whose use and expansion should be encouraged.

Other Choke Points: The Malacca Strait

Essentially all traffic between the Far East and points west of Singapore passes through Malacca – according to the International Maritime Organization, at least 50,000 ships sail through this strait every year – many, many more than just tankers. At its narrowest point in the Phillips Channel of the Singapore Strait, Malacca is only 1.7 miles wide creating a natural bottleneck, as well as potential for collisions, grounding, or oil spills.

Sovereignty over the waters of the Malacca Strait is divided between Singapore, Malaysia and Indonesia. It is doubtful that any of these three states might wilfully attempt to close the strait or attack vessels transiting through them, but the possibility of attacks on the part of non-state actors – as well as of accidents with environmental consequences that would require at least temporary closure of the strait to navigation – must be considered. The Malacca Strait is frequently associated with endemic acts of piracy: we shall speak of non-state actors as a potential source of threat.

When a distinction is made between different types of vessels and between local and long-distance traffic, it is shown that crude oil tankers (and LNG tankers) are among the least vulnerable categories of ships transiting the strait. Bateman et al8 recognize that "A successful terrorist attack on a crude oil tanker could cause massive economic and environmental damage" but believe that this is unlikely. Experience in the "tanker war" (during the Iran-Iraq war) demonstrated that tankers are more resilient targets than normally recognized. Furthermore, "These vessels are also less vulnerable to piracy or sea robberies when underway due to their size and speed. It is virtually impossible, and certainly highly dangerous, for a small craft to attempt to get alongside such a large vessel travelling at its normal operational speed." We should note, however, that the successful hijacking of the Saudi tanker Sirius Star off the coast of Kenya in November 2008 appears to contradict this conclusion.

An analysis conducted by the Institute of Defence and Strategic Studies (IDSS) in Singapore,[9] confirmed that the vast majority of attacks are on the smaller, more vulnerable vessels carrying trade across the Straits or employed in the coastal trade on either side of the Straits rather than oil or LNG tankers.

It is to be noted that the Lombok Strait between the islands of Bali and Lombok in Indonesia to access the South China Sea is a valid alternative for larger vessels.

The Bab-el-Mandeb

Bab el Mandeb is a strait located between Yemen on the Arabian Peninsula and Djibouti, north of Somalia in the Horn of Africa, and connecting the Red Sea to the Gulf of Aden. It is of importance to all tanker traffic from the Gulf to the Mediterranean, which normally includes tankers directed to North West Europe and the United States. Alternatively, this traffic can also circumnavigate Africa and very large crude carriers, which cannot pass through Suez, routinely follow this alternative route.

The domestic security situation in Yemen justifies some concern. Not only has the country become a haven and redeployment base for elements linked to the al-Qaeda, but the danger of state failure and decline comparable to neighboring Somalia is real. This may well create conditions whereby non-state actors may engage in violent action against oil targets in the strait.

That said, piracy has become endemic not just in the strait but in the entire offshore area of Yemen and Somalia, reaching out to offshore Oman on one side and offshore Kenya on the other. Therefore, the issue is not specifically Bab el Mandeb, but more generally security of navigation at sea in the Gulf of

Aden and Indian Ocean, and will be discussed in the paragraph devoted to security in the high seas.

Panama

Panama is not important for Europe and has limited importance for oil traffic globally. Approximately 0.5 mb/d of crude oil and products transit through the Panama Canal. Large oil carriers cannot pass through the canal.

Suez

The Suez Canal, like the Panama Canal, is not an international waterway, but a transit facility entirely controlled by Egypt. Consequently, acts of piracy or terrorism against ships in transit would indicate a severe lapse of security conditions in the country, which appears unlikely at this time. In 2008, 146.7 million tons of crude oil and products transited through Suez, equal to 3 mb/d.

Since the canal has no locks, the only serious limiting factors for the passage of tankers are draft and height due to the Suez Canal Bridge. The current channel depth of the canal allows for a maximum of 16 m of draft, meaning many fully laden supertankers are too deep to pass through fully laden. Improvements are envisaged so that in 2010, the maximum draft will increase to 22 m, in order to allow supertankers. Until then, supertankers must discharge part of their cargo at the entry of the channel and reload it at the other end, transported along the way by the SUMED pipeline, which has a capacity of about 2.5 million bbl/d.

All in all, the Suez Canal/SUMED system, notwithstanding past interruptions, strikes the observer as being very reliable and unlikely to face interruptions.

Turkish Straits

The prospect of greatly increased tanker traffic across the Turkish Straits – in particular, the Bosphorus – has been a cause for concern for the Turkish government and international observers for years now. Natural factors include the shape of the straits, with the narrowest point in the Bosphorus no more than 700m across, numerous bends, and significant currents.

Institutional factors include the fact that according to the Montreux Convention of 1936, passage through the straits is free, to the extent than even pilotage is not obligatory and no tolls are imposed. Consequently, no alternative commercial route can compete. The only cost for utilizing the Straits is the waiting time at the entrance, which of course discourages the installation of costly traffic regulation and control equipment. Environmental factors include, primarily, the consideration that the Bosphorus is today entirely encapsulated in the Istanbul urban area, and any accident would have immediate impact on a very large number of people.

The number of tankers transiting the strait has reached an average of 28 per day, in excess of 10,000 per year in the last three years. Tankers sometimes have had to wait for permission to transit in the southbound direction. In short, traffic congestion at the Bosphorus adds to the cost of shipping but has not reached crisis proportions. The Turkish Straits are the sole outlet for oil exported from Russia, the Caucasus and Central Asia through terminals located on the Black Sea. If the CPC is augmented as planned (1.35 mb/d by 2014), traffic through the Turkish Straits could well increase by 1 mb/d – approximately 45 percent above current levels. This would certainly represent a challenge for safety of navigation through the waterway.

Investing in by-pass pipelines that may drastically reduce the number of tanker passages would appear to be wise policy. There are three main pipeline projects currently on the table: the Samsun/Ceyhan project (aka TAPCO - Trans-Anatolian Pipeline Company), the Burgas/Alexandroupolis project and the Costanta/Trieste project (aka PEOP - Pan European Oil Pipeline).

Baltic Sea

The Baltic Sea is an enclosed body of water, and an accident may have serious environmental consequences. In this, the Baltic is a case similar to the Mediterranean, only smaller and, consequently, possibly even more vulnerable. However, it is not appropriate to consider the whole sea as a choke point. Rather, the difficulty may be defined as the passage of the Danish Straits, which is indeed very narrow. The potential for a major increase of Russian exports through the Baltic is therefore likely to raise issues for navigation through the Baltic Straits.

4.2 Threats to Navigation outside Choke Points

An analysis of accidents and piracy attacks to oil tankers in particular shows that the largest number of significant events took place at a considerable distance from the "choke points" inviting a consideration of conditions of shipping in a much broader spectrum of situations.

We shall discuss two specific categories of threat, which have attracted considerable attention in recent times: piracy attacks and pollution from accidents.

Global Piracy

According to the website of the ICC International Maritime Bureau's Piracy Reporting Centre (IMB),[10] piracy attacks around the world more than doubled to 240 from 114 during the first six months of 2009 compared with the same period in 2008. Confirming a trend already registered in previous months, the rise in overall numbers was due almost entirely to increased Somali pirate activity off the Gulf of Aden and east coast of Somalia, with 86 and 44 incidents reported, respectively.

The IMB maintains a Live Piracy Map which records all actual and attempted attacks for the current year and the most recent four years.[11] It is evident from the map that attacks have been concentrated in three broad areas:

- in the Gulf of Guinea, primarily in Nigeria, near Lagos or Port Harcourt
- offshore Somalia
- in the proximity of Singapore or offshore the east coast of peninsular Malaysia.

In the case of Nigeria and Somalia, piracy at sea is obviously a reflection of political problems on land. For Nigeria, the government in charge has not succeeded in curbing domestic violence: this makes external intervention touchy, as the government should in principle call for outside support in combating piracy, and has not done so nor is it likely to do so. Similarly, piracy in offshore Malaysia is a problem because it is obviously the responsibility of the Malaysian government to deal with the issue.

Somalia is a case of a failed state, and there is no expectation that a nonexistent Somali government may act to curb the phenomenon. It is also the most worrisome area because of the importance and daring of the attacks that have been perpetrated.

The most recent and extraordinary case has been the hijacking of the Saudi tanker Sirius Star 450 miles off the coast of Kenya on November 17, 2008: all about this event has been unprecedented: the distance from the coast, the size of the vessel (318,000 DWT, 330 m of length, one of the largest tankers in the world), the volume of oil transported (2 million barrels), the ransom that was finally paid (reportedly $3 million). Thus, the hijacking of the Sirius Star represents a turning point in the record of piracy at sea and possibly also in the international reaction to this phenomenon. Obviously, if such a large ship can be successfully attacked, all ships are vulnerable. And if an attack can take place at such a distance from the coast, the discussion of choke points is pretty much irrelevant. Preventing and combating piracy must take an entirely new dimension.

The Danger of Oil Spills in Enclosed Seas

According to ITOPF (International Tanker Owners Pollution Federation),12the number of medium and large size spills has greatly decreased over the years. With the decrease in numbers, the total volume of oil spills has also decreased, although data show very clearly that a few very large accidents are responsible for most of the damage – therefore even a single large accident in the future (such as the one in the Gulf of Mexico in 2010) may change the picture quite radically.

Limitations to freedom of navigation imposed because of environmental concerns may affect future European energy supply especially with respect to the Mediterranean Sea. The Baltic is also a problem, but much less oil transits through there. The Gulf, the Red Sea and the Black Sea also are potentially highly problematic, but the "political equilibrium" between oil and environmental interests in those areas is very much more in favor of oil interests and action to limit tankers' freedom of navigation accordingly less likely.

Tanker Traffic in the Mediterranean

A study of maritime traffic flows in the Mediterranean Sea was recently concluded by Lloyd's Marine Intelligence Unit on behalf of REMPEC in the context of the SAFEMED project sponsored by the European Commission.[13] The study asserts that the most significant change in overall traffic patterns in the Mediterranean in the coming years will be the development of export routes for crude oil from the Caspian region, which is currently shipped predominantly via Black Sea ports through the Bosphorus. North European demand for energy is likely to see an increase in LNG transits via the Mediterranean from gas fields in the Arabian Gulf and the Far East. If planned LNG terminal developments actually take place, the density of LNG tanker deployment around the Italian coastline will increase significantly.

Of the three main source regions discussed subsequently by the Euromed energy ministerial conferences (Athens 2003 and Rome 2003) to develop pipeline infrastructure so as to reduce maritime transport of hydrocarbons, the prospect for pipelines from North Africa or the Middle East appear remote, because there is no experience of major sub-sea oil transport pipelines (while these are well proven for gas), and overland pipelines would greatly increase the distance to be covered. However, in the case of crude oil from Russia and the Caspian across the Balkans, the logic is much more stringent. Nevertheless, as noted in the discussion of Turkish Straits' bypasses, little progress towards implementation of any of these pipelines has taken place so far.

Conclusion: Scenarios of Supply Interruption and Potential Remedies

The general conclusion that can be drawn from this discussion is that there is no scenario of interruption of maritime oil and gas transportation which may cause a severe physical shortage of oil, in general and specifically for Europe. Even the most problematic of cases – the attempted closure of the Strait of Hormuz – could not have the catastrophic consequences sometimes discussed: a good part of Gulf production could be evacuated from ports outside of Hormuz, and the strait is unlikely to be totally closed. Whatever disturbance to passage would not last more than two-three months. The shortage of crude oil created by such circumstances could be dealt with through draw-down of strategic stocks held by governments under the IEA program.

It was also found that, in almost all cases, existing potential tensions could be easily allayed if responsible governments took the necessary steps to create alternatives, notably pipeline bypasses, or to curb illegal activities.

It was argued that the main reason preventing the required investment in transportation alternatives is the lack of a well-functioning market mechanism for burden sharing. Although excessive reliance on congested straits may cause losses to individual shippers because of increased waiting time, increased insurance rates or piracy acts, this does not translate in the willingness to participate in investment which should be carried out by third parties. In most cases, the temptation of free riding prevails, and no one underwrites the required investment. Where passage must be paid for, the resulting income stream supports investment to increase capacity and accommodate growing demand.

Supply interruptions consequent to closure of major sea lanes may be addressed by the European Union directly and indirectly. Directly, the EU can more forcefully pursue projects aiming at reducing vulnerabilities, such as excessive passage of tankers through the Turkish Straits. Eventually, "congestion charges" may need to be imposed, not differently from what is done in the case of private cars in central London and several other major cities. Freedom of navigation and the right to free passage cannot be sacrosanct principles to be applied in all circumstances, even where resources are objectively scarce. Indirectly, the EU could have agreements with partner countries aiming at facilitating investment in infrastructure that may reduce vulnerabilities and the danger of accidents and engage in promotion of international compacts to enforce ever more stringent standards for oil, products and chemical tankers.

Endnotes

1. International Energy Agency, "IEA Response System for Oil Supply Emergencies," December 2008, 11.
2. *Financial Times*, April 2008.
3. "Network Oil Infrastructures - An Assessment of the Existing and Planned Oil Infrastructures within and towards the EU," Commission Staff Working Document accompanying the Green Paper "Towards a Secure, Sustainable and Competitive European Energy," COM(2008) 737.
4. Caitlin Talmadge, "Closing Time: Assessing the Iranian Threat to the Strait of Hormuz," International Security 33, no. 1 (Summer 2008): 82–117.
5. Talmadge, ibid.
6. US Congress, Joint Economic Committee, "The Strait of Hormuz and the Threat of an Oil Shock", July 2007 available at http://www.house.gov/jec/studies/2007/Straight%20of%20Hormuz%20Study.pdf
7. The pipeline has been operating at much less than its rated maximum capacity because most customers of Saudi Aramco prefer to lift from Ras Tanura in the Gulf rather than from Yanbu. Nevertheless, a study conducted for the Baker Institute of Public Policy (Ewell, Brito and Noer An Alternative Pipeline Strategy in the Persian Gulf, http://www.rice.edu/energy/publications/docs/TrendsinMiddleEast_AlternativePipelineStrategy.pdf) concluded that "the throughput of the existing pipeline system can be significantly increased with the use of drag reduction technology. As many as 11 MBD could be moved through the combined Petroline-IPSA system for an investment of $600 million. Alternately, a noticeable increase in Petroline throughput can be obtained for as little as $100 million. All options require an additional annual cost of roughly $50 million to hold DRA (drag reduction agent) inventory, or additional investment to build DRA production capacity in Saudi Arabia. The additional cost of moving oil during a crisis by this route is less than $1 per barrel. This is clearly economically feasible in the event of a SoH (Strait of Hormuz) closure; the price of oil will rise more than $1 per barrel in this case, covering the additional costs. It is just as clearly not economically viable as a routine peacetime alternative: Yanbu exports are already economically unattractive (compared to Ras Tanura) for most Saudi customers, and adding DRAs would increase costs of oil at Yanbu even further."
8. This discussion is based on Sam Bateman, Joshua Ho and Mathew Mathai, "Shipping Patterns in the Malacca and Singapore Straits: An Assessment of the Risks to Different Types of Vessel," *Contemporary Southeast Asia* 29, No. 2 (2007):309–32.
9. Sam Bateman, Catherine Zara Raymond, Joshua Ho, *Safety and Security in the Malacca and Singapore Straits — An Agenda for Action*, Singapore: Institute of Defence and Strategic Studies, 2006.
10. http://www.icc-ccs.org/index.php?option=com_content&view=article&id=30&Itemid=12
11. The map is accessible at http://www.icc-ccs.org/index.php?option=com_fabrik&view=visualization&controller=visualization.googlemap&Itemid=219
12. http://www.itopf.com/
13. "Study of Maritime Traffic Flows in the Mediterranean Sea" Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), July 2008.

Bibliography

- Aissaoui, Ali. "Algeria: The Political Economy of Oil and Gas." OIES, Oxford 2001.
- Aissaoui, Ali. "Managing Hydrocarbon Resources in a New Era: the Call from Algeria." Oxford Energy Comment, OIES, July 2000.
- Alexandersson, Gunnar. *The Baltic Straits*. Martinus Nijhoff Publishers, 1982.
- Algerian Ministry of Energy and Mines, http://www.mem-algeria.org/francais/index.php
- Bateman, Sam, Joshua Ho and Mathew Mathai. "Shipping Patterns in the Malacca and Singapore Straits: An Assessment of the Risks to Different Types of Vessel." *Contemporary Southeast Asia* 29, no. 2 (2007): 309–32.
- Bateman, Sam, Catherine Zara Raymond and Joshua Ho. *Safety and Security in the Malacca and Singapore Straits – An Agenda for Action*. Singapore: Institute of Defence and Strategic Studies, 2006.
- Boué, Juan Carlos. "The Internationalisation Programme of PDVSA." OIES, Oxford, 2004.
- Boué , Juan Carlos. "Venezuela: The Political Economy of Oil." OIES, Oxford, 1993.
- Bower, Tom. *Oil: Money, Politics, and Power in the 21st Century*. Harper Press, 2010.
- BP corporate website.
- BP Official Website: "Kovykta Project" http://www.tnk-bp.com/operations/exploration-production/projects/kovykta/ last accessed May 13, 2010.
- *BP Statistical Review of World Energy*, various years.
- Center of Systemic Peace, http://www.systemicpeace.org/conflict.htm. Accessed May 15, 2010.
- Chapman, Duane. "Gulf Oil and International Security: Can the World's Only Superpower Keep the Oil Flowing?" In *Energy Security and Global Politics: The Militarization of Resource Management*, eds. Daniel Moran and James Russell. London, New York: Routledge, 2009.
- Energy Information Administration website, http://www.eia.doe.gov/
- Energy Information Administration. "World Oil Transit Chokepoints." Country Analysis Brief, January 2008, available at http://www.eia.doe.gov/cabs/World_Oil_Transit_Chokepoints/Background.html
- European Commission, "Network Oil Infrastructures - An Assessment of the Existing and Planned Oil Infrastructures within and towards the EU." Commission Staff Working Document accompanying the Green Paper "Towards a Secure, Sustainable and Competitive European Energy." COM (2008) 737.
- Ewell, M. Webster, Dagobert Brito and John Noer, *An Alternative Pipeline Strategy in the Persian Gulf*, available at http://www.rice.edu/energy publications/docs/TrendsinMiddleEast_AlternativePipelineStrategy.pdf
- Financial Times. "Russians Step Back from TNK-BP." January 24, 2010. http://www.ft.com/cms/s/0/ae2a3c34-090e-11df-ba88-00144feabdc0.html
- Forest, James, and Matthew V. Sousa. *Oil and Terrorism in the New Gulf: Framing U.S. Energy and Security Policies for the Gulf of Guinea*. New York: Lexington Books, 2006.
- Giroux, Jennifer, and Caroline Hilpert. "The Relationship between Energy Infrastructure Attacks and Crude Oil Prices." *Journal of Energy Security*, October 2009.
- Green, Mathew and Catherine Belton. "Gazprom Plans Africa Gas Grab." *Financial Times*, January 4, 2008.
- Gulf Research Center, Dubai, various working documents.
- Hanelt, C.P., G. Luciani and F. Neugart, eds. *Regime Change in Iraq: the Transatlantic and Regional Dimensions*. EUI and Bertelsmann Stiftung, 2004.
- Heidelberg Institute for International Conflict Research. "Conflict Barometer 2010." http://hiik.de/

en/konfliktbarometer/pdf/ConflictBarometer_2009.pdf

- Hertog, Steffen. "Petromin: The Slow Death of Statist Oil Development in Saudi Arabia." *Business History* 50, no.5 (Autumn 2008).
- Ibeanu, Obey and Robin Luckham. "Nigeria Political Violence, Governance, and Corporate Responsibility in a Petro-state." In *Oil Wars*, edited by Mary Kaldor, Terry Karl, Yahia Said. MacMillan, 2007.
- International Crisis Group. "Fuelling the Niger Delta Crisis." *Africa Report* no. 118 – 28 September 2006.
- International Crisis Group. "Nigeria: Ending Unrest in the Niger Delta." *Africa Report no*. 135, December 5, 2007.
- International Crisis Group. "The Swamps of Insurgency: Nigeria's Delta Unrest." *Africa Report* no. 115, August 3, 2006.
- International Energy Agency. "IEA Response System for Oil Supply Emergencies." December 2008
- International Energy Agency. "IEA Response System for Oil Supply Emergencies 2010."
- Khadduri, Walid. "Iraq: Future of the Oil Industry." In *Regime Change in Iraq: the Transatlantic and Regional Dimensions* edited by C. Hanelt, G. Luciani and Neugart. EUI and Bertelsmann Stiftung, 2004.
- Khan, Sarah Ahmad. *Nigeria: the Political Economy of Oil*. Oxford, 1994.
- Liukkonen, Seppo. "Technical Requirements for Year-round Baltic Sea Tanker Traffic." available at http://www.google.ch/search?client=opera&rls=en&q=tanker+navigation+baltic+straits&sourceid =opera&ie=utf-8&oe=utf-8
- Marcel, Valerie. *Oil Titans*. Brookings Institution Press, 2006.
- Maull, Hans, and Otto Pick *The Gulf War: Regional and International Dimensions*. London: Pinter, 1989.
- *MEES*, various issues.
- "Middle East: History and Prospects." *Journal of World Energy Law and Business* 1, no.1, 2008.
- Middleton, Roger. "Piracy in Somalia." Chatham House Briefing Paper, October 2008.
- Ministry of Energy and Mining, Sudanese Petroleum Corporations.
- Ministry of Oil, State of Kuwait: http://www.moo.gov.kw/Default.aspx?pageId=198
- Mitchell, John, Peter Beck, and Michael Grubb. "The New Geopolitics of Energy." Royal Institute of International Affairs, 1996.
- Mommer, Bernard. "Fiscal Regimes and Oil Revenues in the UK, Alaska and Venezuela." *OIES*, June 2001.
- Mommer, Bernard. "Sovereignty and Oil." Oxford Energy Forum #50, August 2002.
- Moran, Daniel and James A Russell. "Introduction: The Militarization of Energy Security." In *Energy Security and Global Politics: The Militarization of Resource Management*, eds. Daniel Moran and James Russell. London, New York: Routledge, 2009.
- Morris, Daniel. "The European Union's African Oil Supplies: Secure?" Research report for the SECURE project (manuscript).
- O'Loughlin, John, Frank Witmer, Thomas Dickinson, Nancy Thorwardson, Edward Holland. Eurasian Geography and Economics 48 (2) March-April 2007 http://bellwether.metapress.com/content/73t6m75244576w90/
- OPEC. *Annual Statistical Bulletin 1987*.

- OPEC. *Annual Statistical Bulletin 2008*.
- Parra, Francisco. *Oil Politics: A Modern History of Petroleum*. London, New York: I.B. Tauris & Co. Ltd, 2009.
- Rahim, Saad. "Regional Issues and Strategic Responses: The Gulf States." In *Energy Security and Global Politics: The Militarization of Resource Management* edited by Daniel Moran and James Russell. London, New York: Routledge, 2009.
- Royal Dutch Shell corporate website.
- Saudi Aramco corporate website, www.saudiaramco.com
- Shell official website, "Gazprom, Shell, Mitsui, Mitsubishi Sign Sakhalin II Protocol." http://www.shell.com/home/content/media/news_and_library/press_releases/2006/sakhalin_protocol_21122006.html. Accessed on May 13, 2010.
- Simonoff, J.S., C.E. Restrepo and R. Zimmermann. "Trends for Oil and Gas Terrorist Attacks." Institute for Information Infrastructure Protection Research Report No. #2 November, 2005.
- Stevens, Paul. "Resource Nationalism and the Role of National Oil Companies in the Middle East: History and Prospects." *Journal of World Energy Law and Business 1*, no. 1, (2008).
- "Study of Maritime Traffic Flows in the Mediterranean Sea." Report Prepared for the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC). July 2008.
- Talmadge, Caitlin. "Closing Time: Assessing the Iranian Threat to the Strait of Hormuz." *International Security* 33, no. 1 (Summer 2008): 82–117.
- The Uppsala Conflict Data Program, http://www.pcr.uu.se/research/UCDP/index.htm
- Ukiwo, Ukoha. "From 'Pirates' to 'Militants': A Historical Perspective on Anti-state and Anti-oil Company Mobilization among the Ijaw of Warri, Western Niger Delta." *African Affairs*, 106/425, 587–610.
- US Congress, Joint Economic Committee. "The Strait of Hormuz and the Threat of an Oil Shock." July 2007, available at http://www.house.gov/jec/studies/2007/Straight%20of%20Hormuz%20Study.pdf
- Waddams, Frank C. *The Libyan Oil Industry*. Johns Hopkins, 1980, 251-53.
- Wennman, Achim. "Breaking the 'Conflict Trap'? Addressing the Resource Curse in Peace Processes." *Global Governance*, 2010 (forthcoming).
- White, Matthew. *Historical Atlas of the Twenty First Century*. http://users.erols.com/mwhite28/20centry.htm. Accessed May 21, 2010.
- Yergin, Daniel. *The Prize*. Simon and Schuster, 1991.

Consulted websites:

- ICC Commercial Crime Services:
- http://www.icc-ccs.org/index.php?option=com_content&view=article&id=30&Itemid=12
- The International Tanker Owners Pollution Federation Limited:
- http://www.itopf.com/

Functioning of the International Oil Markets and Security Implications*

Introduction

Energy security is primarily a function of investment. If investment in new capacity, logistics and transmission, and emergency preparedness is timely and adequate, energy security will be guaranteed.

Investment in a market economy is a function of the expected revenue stream, which in turn is a function of prices. Reliable and predictable price signals are a prerequisite for adequate investment. If prices are very volatile and/or unpredictable, enterprises will not be confident enough to invest. Energy security will be imperiled.

A well-functioning market is, therefore, a key component of security. Ideally, the market should generate stable and predictable prices, i.e. prices that can be modeled on the basis of structural factors within a sufficiently narrow band to allow enterprises to have a reasonably good vision of the revenue stream that their investment might generate.

The main obstacle to the security of supply of oil and gas is the growing volatility of prices and their fundamental unpredictability. This leaves enterprises exposed to very high risk and, in fact, will discourage some of them. In these circumstances, it is to be expected that enterprises will tend to be conservative and underinvest.

Security itself is also dependent on prices. Customers feel secure if they can buy all the energy they need at prices that they can afford. A purely physical concept of security (meaning availability of the quantities of energy that are in demand at any moment in time) has little meaning, because demand varies with price. There always is a price at which demand will exactly equal supply – it may be a very high price, however, at which some final customers may not be able to satisfy their "essential needs." Oil, specifically, has a global market and any supply interruption that one can think of is quickly translated into higher prices, this being the key mechanism for rationing demand and redistributing supplies among different bidders. In the end, oil is almost never physically unavailable.

But even "essential needs" are a function of prices, in the sense that in the long run customers will adjust their consumption habits to the expected cost of energy and their disposable income. In the short term, such adjustments may be difficult, and what creates insecurity is the experience of price volatility, the fact of being surprised by sudden jumps in prices which were not and could not be expected.

Hence, energy security is as much a matter of perception as of objective availability. Consumers make decisions on the basis of the historically prevailing level of prices: energy may be expensive or cheap – in the sense of absorbing a large or small share of their consumption basket – and their lifestyles will adjust accordingly. Lifestyles and per capita energy consumption in Europe and Japan are quite different from those prevailing in North America, because for decades energy has been relatively expensive in the former and considerably cheaper in the latter. Nevertheless, consumers in Europe and Japan are not insecure because they have to devote a larger share of their income to energy than their North American counterparts – their level of consumption has adjusted to the price environment.

Well-functioning oil and gas markets, therefore, are not only a prerequisite of energy security through their influence on investment and future availability; they are a component of security, because volatile

** This paper was written by Giacomo Luciani of GRCF* and unpredictable prices are part of the definition of insecurity.

This paper looks at the evolution of prevailing international oil price regimes over the past decades as well as at past attempts at stabilizing prices and the reasons why they failed. This historical background is necessary to better understand the causes of today's growing volatility and potential remedies to the same. The current reference pricing regime will then be introduced, and the debate on the causes of increasing volatility and whether the market responds to fundamentals or is dominated by speculators will be summarized. This debate is very much underway.

Next, we shall discuss the structural causes of volatility in the oil and gas markets. It is normally accepted that, even if the current market is reformed and its functioning improved, volatility can be contained but not eliminated. What institutional arrangements can we envisage which will create enough long-term convergence in prices whereby investment will be sufficient to meeting future demand?

In the concluding section, we shall discuss how this relates to other aspects of our analysis of oil security, notably the geopolitical aspects and policies for strategic storage and cooperation with the exporting countries.

1. A Short History of Oil Price Regimes

Figure 1 is a very well known and widely quoted representation of oil prices in nominal and real terms since the inception of the oil industry. The figure shows that oil prices were extremely volatile in the early days of the industry because output increased suddenly whenever there was a new discovery, then declined rapidly as fields were uncontrolled due to the law of capture in the US and poor technological understanding of petroleum geology.

The industry experienced one long stretch of stable oil prices, from the early 1920s to the early 1970s: a 50-year period of progressive expansion with slowly declining prices, which was made possible by very large discoveries in the Middle East coupled with oligopolistic control on supplies by the famous seven (or eight) sisters, the major international oil companies of the time. This control – albeit slowly yet systematically eroded by "oil independents" and other newcomers – succeeded in guaranteeing the "orderly" development of capacity, in line with the rapid growth of demand. Oil supply security was guaranteed by the seven sisters, although not necessarily at the lowest possible price to the final consumer, nor with the fairest possible distribution of financial benefits between the various parties involved.

The seven sisters lost control of the oil market between 1969 and 1973. In 1969, Muammar Qaddafi seized power in Libya in a bloodless coup, overturning the Sanusi monarchy. Very soon, he nationalized some of the companies operating in the country and asked for significant concessions from the others. The nationalized companies called for a boycott of Libyan oil, as they had resorted successfully to a boycott of Iranian oil in 1950-53. But the boycott failed: Iran joined Libya in challenging the companies, and the so-called Tehran-Tripoli agreements were arrived at. But the latter were not destined to last for long: it had been proved that companies could not resist the demands of major oil exporters, and the balance of power in the industry shifted from the major international oil companies to the major exporting countries.

The companies had unilaterally "posted" a price for the crude they were producing. The role of the posted price was primarily to calculate taxes due to the host governments, avoiding the controversies that would have arisen had "market prices" been used instead. There was, in fact, no transparent and easily observed international oil market at the time.

In 1973, the power of fixing posted prices shifted from the companies to the exporting countries. This opened the door to a period of intense instability in prices, starting from 1973 to 1985. Prices grew rapidly until 1980 and collapsed thereafter.

Prices rose in the first sub-period because of political events: the Yom Kippur war of 1973, the Iranian Revolution of 1978-79, and the beginning of the Iraq-Iran war in 1980. Prices were pushed to historical highs, and OPEC just simply sanctioned the level that was generated by short-term panic buying and supply disruptions. Notwithstanding the opposition of some of its members, notably Saudi Arabia, a longer-term vision of OPEC's interests did not prevail: no consideration was given to the danger of demand destruction and growing non-OPEC supplies – although it was rather clear at that time that significant volumes of oil would be made available to the market from new producing provinces, notably the North Sea, Alaska and Mexico.

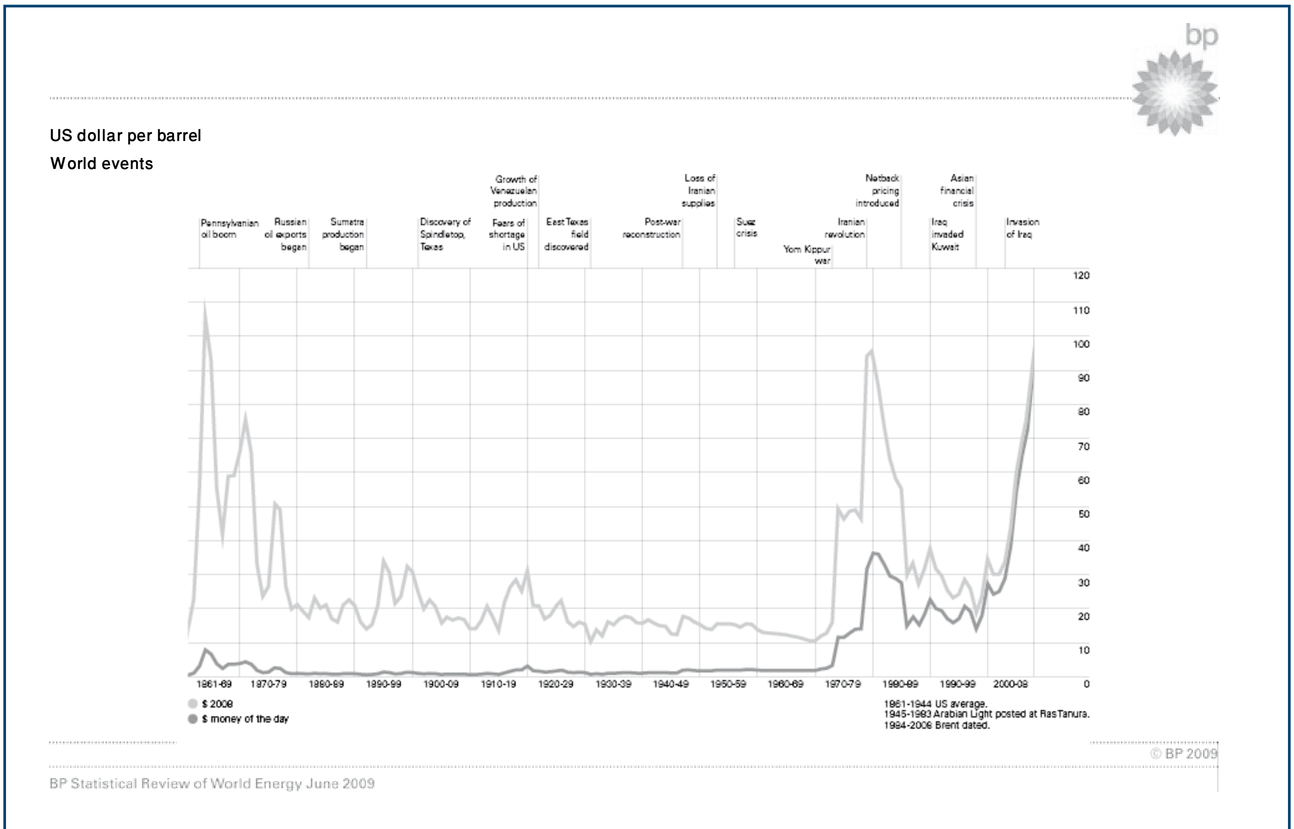
OPEC attempted to defend its posted price by cutting back on production and enforcing quotas on its members. Non-compliance eroded OPEC's solidarity, already badly challenged by multiple conflicts between its Middle Eastern members.

In 1985, Saudi Arabia abandoned the posted price system and resorted to netback pricing. The netback price regime was short lived, lasting only about two years. It led to a collapse in crude oil prices, partly because OPEC quota discipline broke down and production increased, and partly because netback pricing tends to guarantee refiners' margins and encourages refineries to run at full capacity, flooding the market with products and eventually drawing down the netback value of the barrel.

Following this came the era of reference pricing, which is the prevailing regime to date. Reference pricing means that the price of a crude oil which is not freely traded is indexed to the price of a crude oil which is freely traded, plus or minus an adjustment factor which is periodically reviewed by the producing country depending on market conditions. In this system, the producing country can manipulate the adjustment factor, but by far the major influence on the price of any non-traded crude comes from variations in the price of the benchmark crude, to which it is tied.

Two markets have emerged as benchmark for all other crude oils – that is Brent in the UK and WTI in the US. This regime has proven resilient in the face of political disturbances, but volatility has monotonously increased and has exploded since 2007. The reason for increased volatility has been

Figure 1: Crude Oil Prices since 1861-2008



the progressive shift from referencing physical oil prices to referencing futures.

"Initially," writes Robert Mabro, "the marker prices were spot WTI, dated Brent, or spot ANS. The logic is that a marker price must be generated in a physical market where the transactions are sales and purchases of barrels of oil. Thus 'market-related' meant a relationship to prices arising at the *margin* of the physical market. This conforms to a fundamental economics principle that prices are determined at the margin."[1]

However, physical oil transactions became increasingly unreliable because of dwindling physical volumes and the ease with which the market could be influenced. As futures trading developed, originally as an appendix of the physical market intended to provide liquidity, but subsequently to attract trading many times in excess of that of the physical market, the balance of price discovery has shifted from physical oil to futures.

We are now in the midst of a major controversy concerning whether "speculation" is "excessive," or "investors" are simply providers of badly-needed liquidity and better equipped to judge collectively of longer- term trends. Nowadays do oil prices respond to fundamentals or to speculation?

According to some, prices respond to fundamentals, and indeed "investors" or "speculators" are better judges of long-term trends than "commercial" traders, i.e. the oil companies. Throughout the 1990s, and well into the early years of this century, major international oil companies maintained that the price of oil at $18 per barrel (on average in the 1990s) was too high and would prove untenable. This opinion, it should be added, shaped the major companies' investment policies, leading to very conservative investment decisions and a preference for mergers and acquisitions over greenfield development of new projects.

Against this view, a current of opinion insisted that oil is finite, and production will inevitably peak. Various versions of the peak oil theory have been proposed at different times, and heated controversy has characterized this debate.

The futures market signaled a tendency to an increase already in 2002 and early 2003. Prices had risen already in 2000, but this spike had been deemed untenable by a majority of experts. And in early 2003 the expectation was that prices would again fall, following the US and allies' intervention for regime change in Iraq, which would lead to an increase in Iraqi production and exercise pressure on OPEC.

Instead, 2004 saw an unexpected increase in demand and further price increases. The futures market signaled a tendency towards higher prices through a persistent contango, which at the time was deemed unjustified. The market was signaling its fundamental belief that oil would become relatively scarce, due to demand increasing faster than supplies. This is not the same as necessarily expecting a peak: all that is required is an expectation that supply will grow more slowly than demand. Today, most experts would agree that the market was right, and preachers of low oil prices had been wrong.

However, in 2007 and even more so in 2008 the market was shaken by such violent swings that it is impossible to find a rational justification for fundamentals' shifts. There was no dramatic demand increase or supply restriction to justify the doubling of prices between the beginning of 2008 and July of the same year, followed by a dramatic collapse in the latter part of the year. Such swings can only be understood as part of the turbulence which hit financial markets, of which today's futures oil market is part and parcel. The price of oil is therefore highly exposed to the vagaries and disequilibria of the financial markets and has ceased to send a useful signal to corporate decision-makers for the purpose of sanctioning long-term investment.

From the point of view of security of supply, if all that a major disruption can cause is a major swing in oil prices, but the same kind of swing can happen also in the absence of a major physical disruption: then what is the point of worrying about disruptions?

Obviously, it is necessary to address the issue of price stability, and especially of convergence of prices towards a long-term value which may be credibly used for investment decisions.

2. Structural Causes of Oil Price Instability

Oil prices, like the prices of most commodities, are unstable because of well-understood structural causes.

Firstly, upfront investment is the key cost component, while direct costs are relatively less important. This means that once the investment is made and the capacity created, it will be utilized even if prices fall well below the break-even point. It is only if prices fall below direct costs that the producer will consider shutting capacity, and even then it may be costly (in terms of immediate costs or forfeited long term revenue) to shut in capacity.

Secondly, investment gestation times are very long. For a while, the industry boasted that it was able to go from discovery to early production in a much shorter time than in the past, but a few exceptional examples in the offshore of the Gulf of Guinea have since been overshadowed by numerous disaster stories – from the Gulf of Mexico to Sakhalin passing through Kashagan. Whether it is field development, pipeline construction, or refinery construction, this is an industry in which five to 10 years easily pass from the moment the investment is sanctioned to the moment it becomes operational. For all practical purposes, this means that investment is made with little or no knowledge of the returns it will bring when it becomes operational. True, the futures market can mitigate this risk and offers contracts and derivatives several years into the future, but liquidity at such distant maturities is thin and the feasibility of massive hedging of investment is problematic. In fact, very few major projects are financed with risk mitigation from the futures market.

Thirdly, and most importantly, both demand and supply are rigid in the short term. Exhibit 1 reproduces a slide used by Christopher Allsopp and Bassam Fattouh in a presentation given to the Bank of England in June 2008.[2] It summarizes different measures of price elasticity of oil demand estimated by various authors at different times. Short-term price elasticity has consistently been found to be very low, in fact very close to zero. Long-term elasticity is more significant, being estimated in a range of .5-.6 for the OECD countries and much lower for the developing countries. Finally, authors that have repeated the estimation over time have found that price elasticity is declining – a consequence of the fact that oil has been largely substituted by other fuels in uses in which substitution was easy.

Exhibit 1: Oil Demand Price Elasticity

- Oil demand price elasticity is close to zero in short run
- Price elasticity of demand is higher in long run due to substitution and energy conservation but elasticity still quite low
- Declining over time
  - Hughes, Knittel and Sperling (2008): US short-run price elasticity has declined
    - 0.21 to 0.34 over 1975-1980
    - 0.034 to 0.077 for 2001-2006

Studies	Short run	Long run	Sample
Dahl, 1993	–0.05 to –0.09	–0.13 to –0.26	Developing countries
Pesaran *et al.*, 1998	–0.03	0.0 to –0.48	Asian countries
Gately and Huntington, 2002	–0.05 –0.03	–0.64 –0.18 –0.12	OECD Non-OECD Fast growing non-OECD
Cooper, 2003	0.001 to –0.11	0.038 to –0.56	23 countries
Brook *et al.*, 2004		–0.6 –0.2 –0.2	OECD China Rest of World
Griffin and Schulman, 2005		–0.36	OECD
Krichene, 2006	–0.02 to –0.03	–0.03 to –0.08	Various countries

Source: Christopher Allsopp and Bassam Fattouh, "Oil Prices: Fundamentals or Speculation?" (presentation at the Bank of England, June 13, 2008)

Exhibit 2 shows that the income elasticity of oil demand is higher than the price elasticity, meaning that oil demand can effectively be curbed only by reducing disposable income, i.e. through a recession. The very high income elasticity of demand in the developing countries means demand for oil tends to grow more rapidly than GDP in those countries.

Finally, Exhibit 2 indicates that price elasticity of non-OPEC oil supply is also low – a reflection of the points mentioned above about investment being the main cost component and requiring long gestation. Of course, OPEC supply is considered a political variable, and it is expanded or contracted depending on the organization's price target and perception of market conditions – no structural elasticity can be measured.

Exhibit 2: Oil Demand Income Elasticity

- Oil demand more responsive to income than prices
- Responsiveness of oil demand to income been declining over time in OECD
- Developing countries exhibit higher income elasticity than OECD
  - Do not expect income elasticity of oil demand to fall in developing countries very soon

Studies	Long run income elasticity	Sample
Ibrahim and Hurst, 1990	>1.0	Developing countries
Dahl, 1993	0.79 to1.40	Developing countries
Pesaran *et al.*, 1998	1.0 to 1.2	Asian countries
Gately and Huntington, 2002	0.56 0.53 0.95	OECD Non-OECD Fast growing non-OECD
Brook *et al.*, 2004	0.4 0.7 0.6	OECD China Rest of World
Krichene, 2006	0.54 to 0.90	Various countries

Source: Christopher Allsopp and Bassam Fattouh, "Oil Prices: Fundamentals or Speculation?" (presentation at the Bank of England, June 13, 2008)

The combination of rigid demand and rigid supply means that price signals generated by the market are not very effective in balancing demand and supply. Or, conversely, it means that even very small shifts in the balance between demand and supply will provoke large changes in prices. In essence, this market can be truly balanced only through income and investment adjustments, which are slow and generally considered unwelcome. After all, the purpose of energy security is to maintain income and consumption levels, and concluding that demand and supply can only be balanced through declining income levels defeats the purpose.

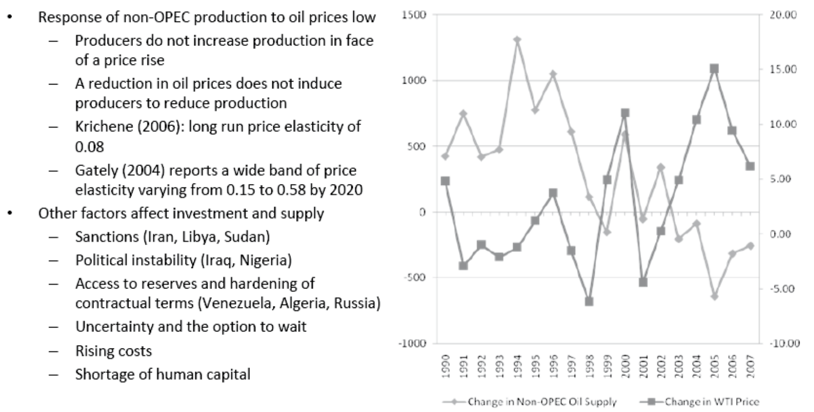
Any discussion of the functioning of the international oil market in view of fostering security must therefore acknowledge that in the short term demand and supply are unlikely to be exactly in balance, and this will cause wide swings in prices. The challenge is to aim at achieving a better balance of demand and supply in the longer term, so that short-term price swings may be understood as oscillations around a central value which is the long-term equilibrium price.

The search for a long-term equilibrium price is further complicated by our poor understanding of the dynamics of both demand and supply. Concerning supply, the most frequent procedure is attempting to estimate non-OPEC supply and calculating the requirement for OPEC supply as the difference between projected global demand and projected non-OPEC supplies. However, estimates of non-OPEC supplies turn out to be significantly off the mark even at very short horizons, such as one year or less. This is all the more surprising since at such short time horizons we know very well which fields are in production and how they behave, and precious few surprises would seem to be possible. Instead, estimates of non-OPEC supplies are almost invariably off the mark, and for the past few years they have been systematically in excess of recorded production.

The lack of success in predicting demand is, in a sense, even more surprising – because here we are dealing with literally billions of decision-makers, whose aggregate behavior should be statistically predictable. In contrast, demand forecasts for any one year are constantly adjusted and by significant margins as the year progresses, and in the end the distance from the original expectation to the recorded result can easily be of the order of 1 to 2 per cent. With .05 price elasticity of demand, this alone justifies a 20 percent swing in prices.

Thus, at any point in time, we really have very little confidence about future demand and supply, and such lack of confidence fundamentally contributes to the perception of insecurity about energy supply. Today, the International Energy Agency (IEA) estimates that investment is insufficient, and as soon as the global economy recovers, the price of oil will again tend to increase rapidly. Fatih Birol has gone on record asserting that this will limit global growth unless investment is increased promptly. In turn, this expectation is influencing "investors" (or "speculators") and justifies the high prices in the back end of the futures curve, which in turn are believed to be the reason why even front end future prices are relatively high, notwithstanding the market is flush with oil. In this world, expectations become reality and have greater influence on prices than actual

Exhibit 3: Supply Response



Source: Christopher Allsopp and Bassam Fattouh, "Oil Prices: Fundamentals or Speculation?" (presentation at the Bank of England, June 13, 2008)

demand and supply. But corporate decision-makers are not convinced that prices will stay high: they see that supply is abundant and read that the recovery will be slow – so is this the right time to invest?

3. Structural Changes in the Supply of Liquid Fuels

In the search for a longer-term equilibrium price for investment, we may have our task facilitated by some important changes which are occurring in the international oil industry.

Conventional crude oil is no longer the sole source of liquid fuels. Non-conventional sources will become increasingly important, and the common feature of non conventional sources is that they are primarily industrial processes in which output is much more easily predictable as a function of investment. The timing and production profile over time also are much more easily predictable.

Conventional oil is the realm of uncertainty. Exploration may or may not be successful, and a discovery may be a giant or a small field. Resources in place are never exactly known, and reserves estimates are constantly updated, generally towards an increase, but sometimes in the direction of a decrease. The time required for developing a field and the development cost per barrel of added capacity vary widely across the spectrum and are not always exactly predictable (Kashagan will serve as an example for a long time). Finally, production from a field generally reaches a plateau rather quickly, but it is not easy to know for how long the plateau will last and how rapid the decline might be thereafter.

In contrast, most unconventional projects are much more predictable. The availability of the resource is not in question, be it oil sands, Orinoco bitumen or oil shale: in fact the available resource is so much greater than what is used, as to be practically infinite. The difficulty is in the cost of the investment, with relatively minor operational issues involved – even the technology is not very demanding. At the time the investment is sanctioned, the investor knows with considerable precision what output he will get from the project, and this output will be sustained for the life of the equipment. In this sense, non-conventional oil projects are much closer to a factory than to a mining operation, although they are a combination of the two. The limiting factor is the transformation capacity, not the availability of the raw material.

This is all the more true for gas to liquids or coal to liquids projects, which are essentially petrochemical ventures.

The incremental capacity obtained through investment in non-conventional oil projects is relatively small relative to the investment – and relative to global supply of crude oil. There is little danger that a sudden rush of non-conventional projects will cause an unexpected increase in supply and a collapse in prices, which may undermine investment. Output increases from non-conventional projects will be gradual and very predictable.

As for conventional oil, predictability may also increase because the frequency of very large discoveries has dwindled to almost zero, while the number of declining provinces is increasing. The probability of a sudden increase in capacity, therefore, is very low.

As declining fields become a growing share of total oil reserves, the importance of enhanced oil recovery (EOR) will increase. The effects of implementing EOR on declining fields cannot exactly be predicted, but the connection between investment and increased capacity is much tighter than with conventional methods. Also, as EOR methods are more widely adopted, the weight of direct costs over investment costs may increase (this depends on the specific EOR technology adopted), and investment and production may become more responsive to prices.

From the demand side, it is not clear whether the development of alternatives to the use of fossil liquid fuels may increase or decrease price elasticity. As mentioned earlier, the evidence appears to be that concentration of oil in those uses in which it is most difficult to substitute has further decreased elasticity. However, the appearance of alternatives in the transportation sector may generate greater responsiveness in demand, if the consumer has – directly or indirectly – the possibility of switching from one fuel or source of energy (or mode of transportation) to a different one.

4. Containing Price Volatility

In the light of extreme price fluctuations since 2007, the attention of politicians and experts has been drawn toward the need to dampen short-term fluctuations and achieve greater reliability of prices.

The pendulum has swung back from the extreme position that advocated exclusive reliance on unregulated markets as optimal to a position advocating reining in of speculators and pursuit of a "fair for all" price.[3]

The experience of the oil price yo-yo of 2007-2009 has been sufficiently traumatic to lead to the emergence of a degree of political consensus on the need to dampen volatility and agree on a price that may be acceptable to all sides. Expressions of concern have been voiced not only by the major OPEC exporters but also by leaders of the major industrialized countries, notably former British Prime Minister Gordon Brown, French President Nicholas Sarkozy[4] and US President Barack Obama. It has been said that a consensus may be emerging to the extent that a "fair" price might be in the region of $65-80/b.

On the basis of this impression, the proposal has been put forward to establish an international committee that would decide on prices[5] or a price band,[6] similar to what happens with interest rates (at the national level, though). But how would such a consensus be implemented and enforced? How could producers and major consumers agree on sharing the burden of implementation (which presumably would require active market intervention)?

Finally, it has been proposed that the major oil-producing countries – notably Saudi Arabia – take a more active role in the price discovery process and engage in direct sales of their crude oil through auctions of forward contracts for physical delivery and acceptance of a secondary market.[7]

4.1 Relying on Longer-term Pricing

Even if speculation is curbed and short-term volatility is successfully dampened, it would be advisable to rely on price signals from longer-term maturities rather than on spot or front month prices. Prices for longer maturities (3 or 6 or 12 months) always fluctuate less than front month prices and are inherently more stable, because they are not influenced by short-term inconsistencies of demand and supply.

There is no overwhelming reason why prices to the final consumer should reflect the spot or front month market. Refiners and retailers have the option of hedging forward and could very well be asked to guarantee a price to their customers or give significant advance notice of any variation. The market will not spontaneously generate such behavior: no oil products retailer has conceived of competing on the basis of guaranteeing a price to its customers for a given period of time. The reason is simple: customers cannot be tied to a specific supplier. They would prefer the supplier that guarantees a price in the longer run for as long as that price is lower than the competition, and switch to the competition as soon as it becomes higher. However, if regulations were adopted making it mandatory for all suppliers to guarantee prices for a given period of time and/or announce changes with sufficient advance notice, the final consumer could not take advantage of prices that may be lower in the short term.

It is normally considered that oil products markets are either free or administered, and the latter frequently means prices that are kept artificially low, because governments are reluctant to pass on price increases for crude oil to the final consumers. Indeed, the extensive reliance on administered prices in the developing countries, notably in the fast growing Asian countries, has been singled out as one reason for the rigidity of demand relative to prices: demand is simply shielded from higher prices.

What is proposed here is not a system of administered prices, but a set of regulations which would in essence encourage refiners and retailers to hedge on the futures market and lock in prices which they offer to their clients. Requesting retailers to "post" prices which can only be changed with, say, three months' advance notice would probably yield the best results: competitors would be able to decide whether to follow the moves of the price leader and price competition would still be possible. If prices need to be guaranteed over a set period of time, adjustments will be more difficult and competition will be discouraged. In all cases, coordination in view of price fixing needs to be repressed.

The combination of advance notice and limits to the frequency of price changes would represent an increase of energy security for the final consumer per se. In theory, the final consumer could use the futures market and derivatives to reduce his risk and enhance his own security even in today's conditions, but in practice this is beyond the means of most consumers. Only large consumers, such as airlines or shipping companies, have done so, and they too are vulnerable to the threat of consumer infidelity whenever their final prices are higher than the competition. Regulations for encouraging systematic hedging would contribute to energy security overall.

4.2 Price Bands

The concept of a price band has been around for some time as a way to dampen volatility through a maximum and minimum price target which would trigger action on the part of producers and/or consumers as the market price approaches or crosses the extremes of the band. OPEC had a notional price band between 2000 and 2005. Robert Mabro, Christopher Allsopp and Bassam Fattouh of the Oxford Institute of Energy Studies have all argued in favor of a band. Behrooz Baik Alizadeh of the Iranian Ministry of Petroleum has written, "In its 109th ordinary meeting in March 2000, OPEC unofficially introduced its price band mechanism to the market. Within this mechanism, in the case of the average OPEC Basket crude price falling under $22/b for more than 10 successive working days, OPEC member states would be obligated to cut their daily production by 500,000 b/d, and in the case of the price exceeding $28/b for 20 successive working days, OPEC would increase production by 500,000 b/d. Although OPEC took advantage of this mechanism only once, increasing production by 500,000 b/d beginning on 31 October 2000, and gave up the whole idea in January 2005, introduction of this mechanism affected the market psychologically and stabilized prices during the period that OPEC was not inclined to change prices beyond specific limits."[8]

The problem with any price band concept is the instrumentation of intervention as the price approaches the limits. In the absence of appropriate instrumentation, it is not at all clear that the market psychology will be affected – indeed the market may be tempted to challenge the band and test the will of governments trying to enforce the same.

A price band may be effective if it is agreed upon by both importing and exporting countries. It is not clear that such an agreement would ever be possible, although at present it appears that the target prices of both sides are very close. The interests of exporters and importers are in structural opposition, and the current convergence is likely to be an exception. However, it may not be excluded that the industrial countries' concern for climate change and their desire to diversify their energy balances away from fossil fuels and specifically oil, and the exporting countries' fear that oil might be penalized as a consequence, have indeed created a new order of priorities in the two sides, such that the importers no longer wish to minimize, and the exporters no longer wish to maximize the price.

Secondly, for the band to be a useful concept it would be necessary to enforce supply restraint on all exporters, not just OPEC. It may be argued that the threat of unrestrained expansion of non-OPEC supplies is fading away, because non-OPEC countries are unable to expand their production very much, and in fact non-OPEC production has already peaked or plateau-ed according to some interpretations. Nevertheless, the importing countries should be ready to defend the lower limit of the band by imposing limitations on imports of oil from non-OPEC countries, if necessary.

In the opposite case of prices reaching the upper limit of the band, OPEC countries would obviously be called to use all of their available capacity to supply a tight market. However, if OPEC were to reach the limit of its capacity and the market still remained tight, then the importing countries should be ready to ration domestic consumption, or use "strategic" stocks (more on stocks later). In theory, this would also require concerted action on the part of all importers – something which is guaranteed to be very contentious and difficult to achieve. In the absence of concerted action, free riding on the part of some would prevail.

A further difficulty has to do with revisions or adjustments to the band. If the band is adjusted very frequently – à la limite, in response to any price movement – it ends up being no restraint at all on volatility. At the same time, a band that is never adjusted is bound to become obsolete and untenable. Finding the optimal middle-of-the-road solution is highly subjective and controversial. If we add that this middle-of-the-road compromise would need to be collectively endorsed by both oil exporters and importers, we may conclude that the task is very difficult indeed.

A price band might be useful if it is intended to limit price volatility only within a specified period of time and involves a market-responsive automatic adjustment mechanism. For example, it may be envisaged that the price band would extend x% above and below a central price equal to the average of observed prices in the previous year. In this way, if the price remains consistently close to the upper or lower limit of the band, the central price for the following year will be adjusted and the band moved up or down. The frequency of adjustment of the central price should be inversely proportional to the scope of the band. A system of very frequent adjustments (e.g. weekly adjustments of the central price to a moving average of the observed price over the previous x months) might be compatible with a relatively narrow band (say 10 percent above or below the central price). This would serve the purpose of dampening very short-term volatility.

However, if the objective is creating a more reliable investment environment, priority should be given to less frequent adjustments and a wider band. The beneficial effect on investment decisions of a broadly-based agreement on a central price is likely to outweigh the uncertainty intrinsic in a relatively broader band.

Finally, as mentioned, the effectiveness of a band depends on its instrumentation. Supply restraint may take the form of output limits or the accumulation of stocks, which in turn could be used to counter excessive price increases. This leads us to the possibility of using intervention stocks in addition to strategic stocks, or some hybrid formula of strategic/intervention stocks.

5. Managing Stocks

In theory, strategic stocks are clearly distinct from commercial or intervention stocks. Strategic stocks are meant to be used in case of supply emergencies and to serve the purpose of guaranteeing energy security. Intervention stocks are meant to maintain prices at a fixed level or within a band. In practice, the distinction is blurred, because the concept of energy security incorporates the notion of affordability, and therefore some notion of a maximum acceptable price. Furthermore, emergencies or disturbances arising from geopolitical events such as wars or revolutions tend to be reflected in price levels more so than in physically available supplies: in the end, demand always is matched by supply. Consequently, strategic stocks whose utilization is based on a strict quantitative criterion (such as is the case for the IEA emergency response mechanism) tend never to be used.

Intervention stocks are normally not very well regarded because in all cases in which the defense of a rigid price through the use of an intervention stock has been attempted, the stock facility eventually went bust. A rigid price regime invites speculation, and eventually market forces overwhelm any stock that might be accumulated.

At the same time, it stands to reason that stocks should be accumulated at times when the price is declining or low and liquidated at times when prices are high or increasing. Accumulating stocks even at times when prices are increasing, as the Bush administration did in the US, appears intuitively irrational.

What this means is that institutions and facilities should be established to manage stocks in a flexible way and in the absence of a fixed price regime. If a band is broadly agreed, as discussed in the previous paragraph, then institutions managing stocks will feel encouraged to sell when the price approaches the top of the band, and buy when it approaches the bottom, but it might be dangerous to impose a rigid rule on the stock managers.

Should governments establish intervention stocks? In theory, managing stocks in a way which is functional to maintaining prices within a band is a profitable operation, which might very well be undertaken by private investors. Investors may choose to buy and sell purely paper barrels or they may decide to hold physical barrels: the latter option is likely to have a beneficial effect on price stability. The objective of government regulations, therefore, should be to encourage private investors to hold physical stocks. Today, individual investors (the doctors and dentists of Chicago fame) and large financial investors shy away from physical barrels and only want to deal in paper.

Encouraging holding physical stocks requires passing legislation that will make it easier to build and maintain storage. This is partly an issue of environmental and fiscal rules, partly an issue of market organization. Physical storage operators (who shall be separate legal entities from the owners of the stored oil) should be empowered to issue certificates convertible in physical barrels: oil deposited into the storage would be exchanged for such certificates, and certificates could be used to withdraw oil from storage. There is nothing exotic about this, but such a facility and a market for the certificates that it might issue does not exist.

Governments may well decide to facilitate this development by establishing an agency to build and manage the storage facility[9] – this can be established at the national or regional level or both – and issue certificates to oil depositors. The possibility of depositing oil would be open to all, including national oil companies of oil-exporting countries. Storage facilities could be established in all appropriate locations, not necessarily in the territory of the country or group of countries establishing the same. In fact, it might be very interesting to establish large storage facilities at critical logistical junctures, such as the Suez Canal or the Malacca Strait, or in conjunction with pipeline projects to bypass the same.

Major trading companies already maintain storage facilities, but the phenomenon is limited[10] and not sufficient to influence crude oil prices. Much larger storage facilities are needed, and private sector initiative may not be attracted to establishing them. Nevertheless, per se the business of operating storage facilities may very well be profitable if investment in physical stocks develops as envisaged here.

Stored oil certificates should be designed and regulated in such a way that they will be accepted as collateral by financial institutions. This would open the possibility for oil exporting countries of "depositing" oil that they cannot sell at prices which they deem convenient, and borrow funds to make up for the temporary shortfall in revenue. Of course, if assumptions about future prices are unrealistic, they may end up defaulting – but this should be a concern of the banks, as is the case for any credit issued against real collateral.

6. Demand Security

In discussions on energy security, producing countries have frequently stated that they are willing to engage in the investment which is required to meet expected future demand, but they need some demand security, i.e. assurance that the demand will be there as expected. In other words, security of supply begs security of demand.

In a free market environment, there can of course be no assurance of future demand. Importing countries are at a loss in responding to the request for demand security, because they possess no tools to guarantee demand. How can this problem be approached?

The establishment of storage facilities where oil could be deposited against certificates that may be discounted at financial intermediaries is, of course, already a step in the right direction. An agreement to consult and coordinate in the accumulation/decumulation of strategic stocks may also be of help. But neither is likely to be viewed as providing sufficient security of demand.

Historically, the gas industry solved the problem through take-or-pay contracts. These were said to place the burden of the volume risk on the buyer and leave the burden of the price risk on the seller. There is no denying that this arrangement, unpopular as it might have become, has allowed the implementation of some very ambitious investment projects, and significant improvement in Europe's energy supplies. But these arrangements were possible only because prices were exogenously generated: gas prices were indexed to oil and oil products prices, to guarantee the competitiveness of gas in marginal uses.

In the case of oil, we cannot think in terms of take-or-pay contracts because the price needs to be internally generated. However, individual countries, including large ones, could conceivably conclude take-or-pay contracts and index the price to signals generated elsewhere in the world. For example, China or India could put in place take-or-pay contracts for volumes of Gulf oil, and index the price to Brent or WTI or some other traded market (e.g. the DME Oman contract).This would provide the Gulf producers with significant demand certainty, and probably would be viewed with considerable anxiety by importers in the US, Japan and Europe. It must be pointed out that we are not quite there yet, although the intensification of relations between the Gulf and the emerging countries in Asia does point in this direction.

The drawback of this arrangement is that it would divide the oil market into price making and price taking segments; it is to be expected that volatility on the price making segment would be relatively higher the smaller the price making segment is relative to the price taking segment. This is the same as saying that oil may be sold on the basis of long-term evergreen contracts or on a short-term basis: price is generated on the short-term market, and this is where all potential demand/supply imbalances will be felt. Such imbalances may be minor when related to global demand and supply, but large when related to short-term trading only.

Today, we have a system which is very close to this: prices are indexed to traded markets that are a very small component of global physical supply and demand. The difference is that there are no proper take-or-pay contracts, only evergreen contracts which envisage neither an obligation to supply on the part of the seller nor an obligation to lift on the part of the buyer. In addition, the price directly reflects all the volatility of short-term markets. But an evolution towards take-or-pay contracts closer to those seen in the gas industry is conceivable.

7. Vertical Integration

Another potential step in the direction of a longer-term perspective to investment in the industry is facilitating vertical integration. In the current downturn, the large, vertically integrated international oil companies have claimed that their investment plans are unaffected by the downturn and based on their long-term strategy.

This may or may not be true, of course. In past years, these same companies have frequently been criticized for allocating larger funds to purchasing their own stock and propping up the value of their shares than in industrial projects proper. They have also extensively engaged in mergers and acquisitions, leading to the disappearance of several independent corporations – a loss of diversity which can only negatively affect the vitality of the species.

At the same time, it is true that large integrated companies "own" their market thanks to their presence at the retail level and the oligopolistic nature of the business. Therefore, they enjoy a considerable degree of demand security, although they face the price risk and are exposed to price volatility as any other player in the industry. Large integrated companies also have a broader capital base and may be better able to continue funding investment projects out of internally generated resources than smaller independents.

Nevertheless, the "old" large integrated companies remain vulnerable to the pressure from financial analysts and investors, who are typically only interested in "returning value" to the shareholders in the short run. The functioning of financial markets does not encourage strategic thinking, as investors can enter and exit a stock at any time, and are mostly interested in short-term appreciation. This is a problem for all industrial corporations, but is an especially difficult problem for the oil companies, whose outlook is structurally long-term.

It is typical of the distorting signals that management receives from the financial market that all attention in recent years has been focused on cutting costs rather than guaranteeing the long-term growth of the company.

It must be noted that security of energy supply is also dependent on the functioning of financial markets and the kind of signals that originate from them – however, we cannot enter here into a discussion on how financial markets might be reformed to encourage longer-term thinking on the part of management.

In any case, the problem which affects the behavior of the "old" large integrated companies does not affect the "new" integrated companies: these are the national companies of the major importers which are venturing internationally in order to improve their security of supply, as well as the national oil companies of the exporting countries which are investing downstream in order to gain better control of their markets. In both cases, ownership remains either entirely or to a large extent in the hands of strategic investors, frequently the state itself, and strategic thinking is encouraged rather than short-term profitability.

The growing role of these companies is a factor increasing energy security because they will invest with a long-term perspective. The activism (or shall we say "aggressive" approach) of Chinese companies to acquiring reserves internationally has frequently been portrayed as being a threat to importers in the OECD – while it should be more properly understood as an example to imitate. Equally, the drive of some national oil companies to integrate downstream, acquiring refining and retailing assets in the importing countries, has frequently been viewed as a threat, as if it entailed a further degree of dependence and loss of control, while in fact it should be viewed as improving security of supply and reinforcing the commitment of the supplier to service his own assets and keeping the market supplied.

Hence, vertical integration is important, and it is good for energy security. The OECD countries should look into ways in which they may encourage more of a strategic behavior on the part of the "old" integrated majors, and preserve the species by putting a limit to the cannibalism represented by mergers and acquisitions. And they should welcome the downstream integration of the national oil companies of major producers, interpreting the will to invest as a commitment to supply.

Conclusion

This paper has argued that the functioning of markets is a key determinant of energy security. Geopolitical and other threats to physical supply may cause price shocks, but, based on historical experience, are unlikely to cause any significant physical shortage. Therefore, insecurity is manifested by price shocks and price shocks are insecurity. However, price shocks may very well originate in the absence of major disturbances to physical supplies, simply as runs originated by investors, or "speculators," which the market does not correct because both demand and supply are rigid relative to prices.

Therefore, price volatility is a threat per se, and in many ways more important and more devastating than potential threats to physical supplies. The cost of price volatility is very high, much higher than the potential cost of possible disruption to physical supply; and it is significant not just in the short run, but even more so in the long run, because of the depressive effect it has on energy investment generally.

Thus, addressing price volatility is a key component of energy security policy.

Unfortunately, there is no easy recipe to dampen price volatility: this paper has reviewed several approaches that may reduce volatility, notably:

- Encourage the freer trading of major crude oil streams, notably those from the Gulf
- Increase reliance on long-term pricing
- Enforce an internationally agreed price band
- Manage stocks
- Offer demand security through take-or-pay contracts
- Encourage vertical integration

None of these approaches is sufficient to stabilize prices, but collectively they may very well succeed in reducing the extreme volatility that has been experienced since 2004. Volatility will never be eliminated because it is a structural feature of the oil industry, but it may be contained, and energy supply would be perceived as being much more secure.

Endnotes

1. Robert Mabro, "The International Oil Price Regime - Origins, Rationale and Assessment," *The Journal of Energy Literature* XI, no. 1 (June 2005): 3-20.
2. Christopher Allsopp and Bassam Fattouh, "Oil Prices: Fundamentals or Speculation?" (presentation at the Bank of England, June 13, 2008).
3. The Oxford Institute for Energy Studies held a conference on oil price volatility in October 2009 at St. Catherine's College. A summary of the discussion, which was held under Chatham House rules, was published in the *Oxford Energy Forum* #79 of November 2009.
4. Gordon Brown and Nicholas Sarkozy, "Oil Prices Need Government Supervision," *Wall Street Journal*, July 8, 2009.
5. Robert Mabro has proposed the creation of an independent commission backed by significant research capability and an international convention that would be expected to set a reference price for oil once a month. ENI has proposed the creation of a global energy agency "which might possess the tools to implement concrete initiatives as needed to stabilize the price of oil" (my translation of Scaroni's original speech, available in Italian from http://www.eni.com/en_IT/attachments/media/speeches-interviews/italian-version-speech-scaroni-G8-energia-25-maggio-2009.pdf)
6. In particular, Bassam Fattouh and Christopher Allsopp, "The Price Band and Oil Price Dynamics," *Oxford Energy Comment*, July 2009.
7. Giacomo Luciani, "From Price Taker to Price Maker? Saudi Arabia and the World Oil Market," Rahmania Occasional Paper, forthcoming.
8. *MEES*, February 9, 2009.
9. Japan, Abu Dhabi and Saudi Arabia have an agreement along these lines. Japan has built storage in Japan itself that is offered to Abu Dhabi and Saudi Arabia free of charge to store its oil. The stored oil belongs to the producer but obviously Japan gains a degree of security because of this. See "Saudi Arabia to Store Oil in Japan" Reuters, December 23, 2009.
10. In May 2010, Vitol sold 50 percent of its global storage business to Malaysia's MISC, a subsidiary of Petronas, the purpose being to attract additional equity to expand the business. Vitol being a privately held company owned by its employees faces difficulty in tapping the equity market and finance expansion. See *Financial Times*, May 17, 2010.

References

- Aissaoui, Ali. 2008. Shaping long term oil price expectations for investment : Is it workable? Is it achievable? *APICORP Commentary* 3, no. 11-12 (Nov.-Dec). http://www.apicorp-arabia.com/html/cms/media/pdf/research/Commentary03112008.pdf
- Aissaoui, Ali. 2009. What is a fair price for oil and what makes $75 a barrel seem fair? *APICORP Commentary* 4, no. 4 (April). http://www.apicorp-arabia.com/html/cms/media/pdf/research/Commentary_Vol_4_No_4_2009.pdf
- Allsopp, Christopher and Bassam Fattouh. 2009. The price band and oil price dynamics. *OIES Comment*, July. http://www.oxfordenergy.org/pdfs/comment_01_07_09.pdf
- Allsopp, Christopher and Bassam Fattouh. 2008. Oil prices: fundamentals or speculation? Presentation at the Bank of England, June 13.
- Diwan, Roger. Forthcoming. The financialization of the oil market and the increasing impact of financial institutions in the pricing of crude oil. Rahmania Occasional Paper.
- Energy Charter Secretariat. 2007. *Putting a price on energy – pricing mechanisms for oil and gas.*
- Fattouh, Bassam. 2007. The drivers of oil prices: The usefulness and limitations of non-structural model, the demand–supply framework and informal approaches. *OIES WPM*, 32. March. http://www.oxfordenergy.org/pdfs/WPM32.pdf
- Fattouh, Bassam. 2008. The dynamics of crude oil price differentials. *OIES WPM* 36, January. http://www.oxfordenergy.org/pdfs/WPM36.pdf
- Fattouh, Bassam. 2008. Prospects of the DME Oman crude oil futures contract. *OIES Monthly Comment*, March. http://www.oxfordenergy.org/pdfs/comment_0308-1.pdf
- Fattouh, Bassam. 2009. Basis variation and the role of inventories: Evidence from the crude oil market. *OIES WPM* 38, January. http://www.oxfordenergy.org/pdfs/WPM38.pdf
- Fattouh, Bassam. 2009. Reinforcing feedbacks, time spreads and oil prices. *Oxford Energy Comment*, March. http://www.mees.com/postedarticles/oped/v52n17-5OD02.htm
- Fattouh, Bassam. 2009. The oil market through the lens of the latest oil price cycle: Issues and proposals. Presentation at the OIES conference on "Oil Price Volatility: Causes and Mitigation Strategies," October 9.
- Fattouh, Bassam. 2010. Price formation in oil markets: Some lessons from 2009. *Oxford Energy Comment*, March.
- Horsnell, Paul. 2007. The dynamics of oil price determination. O*xford Energy Forum* #71, November.
- Kilian, Lutz. 2010. Oil price volatility: Origins and effects. WTO Staff Working Paper ERSD-2010-02: January.
- Luciani, Giacomo. Forthcoming. From price taker to price maker? Saudi Arabia and the world oil market. Rahmania Occasional Paper.
- Luciani, Giacomo. Forthcoming. Price and revenue volatility: What policy options and role for the state. *Global Governance*.
- Mabro, Robert. 2005. The international oil price regime: Origins, rationale and assessment. JEL XI, 1 (June): 3-20.
- OIES Summary. 2009. Conference on "Oil Price Volatility: Causes and Mitigation Strategies." *Oxford Energy Forum* #79, November.
- US Interagency Task Force on Commodity Markets. Interim report on crude oil. http://www.cftc.gov/stellent/groups/public/@newsroom/documents/file/itfinterimreportoncrudeoil0708.pdf

SESSION IV: LNG and Gas Supplies to Europe

Geopolitical Issues of Europe's Future Gas Supply*

Introduction and Definition of the Concept of Geopolitical Risk

The gas industry is gaining an ever-growing importance in the energy system of the European Union (EU) and on the global energy scene. As the 2020 target approaches,[1] the need for using less carbon-producing energy resources becomes more urgent. The targeted use of renewable resources might account for 15 percent of the EU's total energy mix; it naturally follows that a complete halt to fossil fuel usage is not possible in the short or medium term. However, the process of switching to non-fossil energy sources can be accompanied by increased use of more environment-friendly fossil fuels. Natural gas is indeed a particularly adequate alternative to oil and coal, especially for power-producing plants. Gas can be considered to emit half the amount of CO_2 compared to oil and one fourth compared to coal.

The strategic importance of natural gas for the EU is very clear. Until recently, an important share of gas consumed in the EU was produced internally, thanks mainly to the Dutch and British resources. Today, however, imports represent the major supply source. This situation is expected to worsen as fields in the Dutch and British part of the North Sea are rapidly depleting. At this moment, the EU will face the potentially dangerous situation of being forced to import the vast majority of an energy source vital for its functioning.

The major element causing unease among experts and governments is that certain sources of gas supplies to the EU are believed to be vulnerable in the sense that they face the threat of being disrupted or even completely stopped. The reasons for this may lie in a technical issue, a physical impossibility to supply the required volumes of gas, or the inappropriate behavior of one actor in the supply process. This last category, which falls under 'geopolitical risks,' is dealt with in this paper.

For the purpose of this paper, risk could be described as the set of threats imposed on the security of natural gas supply to European Union members and caused by the specific behavior of one or more countries (producing or transit) or non-state actors and by the evolution of global institutions and markets.

1. Theoretical Geopolitical Risks

It seems appropriate, as a theoretical recapitulation, to provide a list of events or situations that could be considered as threats for the supply of natural gas to the EU. At the outset, it must also be stressed that the gas business functions very differently from the oil one, the first reason being the physical characteristics of each energy source. While oil can be put in vessels and shipped all over the world, gas is primarily transported by pipeline. Consequently, the gas market is less prone to experiencing high and unexpected volatility, although gas prices are tied to oil prices.

Until now, the political economy of gas has been much more regional and bilateral as the main instrument used by the market is the take-or-pay long-term contract. There are advantages and disadvantages to this situation. First of all, gas prices are less likely to experience dramatic increases, as a shock in one part of this fragmented market does not necessarily impact another part. Pipeline flows can hardly be reversed unless the pipe is designed to do so, and the customer at the end of the pipe cannot

*This paper was written by François-Loïc Henry (GRCF) also based on work by Stefan Schaar Kruse (Ramboll) and Sohbet Karbuz (OME) be changed. The interdependence of producers and consumers is a fundamental feature of EU gas supplies. On the other hand, if the flow is interrupted or halted, the consuming country experiences great difficulties in accessing other suppliers. The situation becomes particularly dangerous when the country does not possess sufficient storage capacities. In that case, the country is left with no gas at all and is forced to direct its consumption to alternative energies. This is precisely what happened in the Balkan region following a dispute between Russia and Ukraine in 2008-2009.

1.1 Armed Conflicts

So far, no major gas-producing country has been involved directly in a major inter-state conflict (with the exception of the Russia-Georgia war of 2008). In the case of armed conflicts involving oil-producing countries, the situation has proved potentially dangerous even for third parties located in the vicinity of the conflict area. In 1984, for example, during the Iran-Iraq war, Saudi and Kuwaiti oil tankers were attacked while crossing the Arabian Gulf.[2] At that time, Japan was in the first phase of negotiating an LNG deal with Qatar; the negotiations were interrupted and only resumed a decade later. During the 2009 Russia-Georgia war, Georgian officials claimed that Russian bombing had targeted the Baku-Tbilisi-Ceyhan oil pipeline. Close to this pipeline also flows the Baku-Tbilisi-Erzurum gas pipeline (South Caucasus), while other important proposed pipelines could follow the same route. Although the allegation turned out to be false, it caused concern in Europe as it showed that a supply axis was under the threat of collateral damage from a conflict.

However, looking only at countries officially at war gives an incomplete picture as the majority of ongoing conflicts today do not fall within the traditional definition of war.[3] Asymmetrical conflicts appearing within the environment of a civil or intra-state war represent the most important category of armed conflicts now. This has repercussions on the understanding of the security of gas supply, as a producing or transit country that is not per se involved in a war can still represent a threat when a part of its territory is affected by conflict. This is particularly the case if the physical infrastructure lies close to combat zones or within reach of a faction fighting the central government.

It should be underlined that although no major gas producer is currently involved in a traditional war, many are affected in varying degrees by internal conflicts.

War, therefore, could be an important risk for gas trade if:

- a producing or transit country is directly involved in the conflict
- a producing or transit country is located in a region close to the conflict
- a gas pipeline takes a route affected by the conflict

On the basis of historical experience, however, it can be said that armed conflicts, while they have greatly impacted prices and the development of new infrastructure, have rarely been the cause of a major physical disruption. To come back to the example of the 2008 Russia-Georgia war, all the variables tended to indicate a military intervention threatening the oil and gas transportation infrastructure; but nothing happened, showing that the effects of an armed conflict on the gas infrastructure are highly unpredictable and not always damaging.

1.2 Political Instability

The risk associated with regime change in a producing country is linked to the possibility of consequent policy changes affecting gas supplies. Political instability in gas-producing countries has never resulted in a cut-off of the physical flow of gas. However, in some cases, newly-established governments have forced gas buyers to enter into a renegotiation of the existing contracts. However, this is generally the exception as economic interests take primacy over political or ideological interests. The governments of producing countries tend to protect their reputation as reliable suppliers.

To illustrate the risk caused by political instability, we may refer to two contrasting examples: first, Algeria after the death of President Boumedienne and second, Qatar in the mid-1990s.

Following the death of President Boumedienne in 1978, a new administration took charge. They had a drastically different vision from that of the Boumedienne government concerning the country's natural resources. Building on the success of the OPEC, Algeria decided to apply a strategy where high prices were to replace large volumes. The ruling party also held the belief that national natural resources had to be directed toward the fulfilment of long-term domestic requirements and the constitution of strategic reserves.[4]

The direct consequence was a push to get a vigorous increase in the gas export price. When the pipeline to Italy was ready to be operational at the end of 1980, Algeria demanded that the prices received at the Tunisian border be increased by $2 per mmbtu from the price negotiated in 1977 which was $3.5 per mmbtu. The dispute escalated as ENI refused the request. Algeria stopped payments due to Italy for the construction of the pipeline and Italy ordered that all Italian construction and industrial projects in Algeria be frozen. As Aïssaoui notices, the battle became an attempt to change the netback pricing formula for oil-gas price parity. Italy had to cede and accept a price of $5.13 per mmbtu for gas delivered to it, and some other European countries importing gas from Algeria also had to accept the modification of the pricing formula.

Eventually, the damage done to Algeria's reputation by this issue of breach of contract was more significant than the short-term monetary gains made by the country.

In contrast, the Qatari experience proves that sometimes even when countries undergo changes at the level of the head of state, no disruption of gas export conditions appears. In 1995, as the first trains of LNG shipment from the Qatari North field to Japan were almost finalized, the Crown Prince of Qatar Shaikh Hamad bin Khalifa Al-Thani deposed the Emir, his father Shaikh Khalifa Bin Hamad Al-Thani, in a non-violent coup. The new ruler was a proponent of the development of gas exports and privileged good relations with the West. Hence, no alteration of the contractual obligations took place.

The death of the President of Turkmenistan Saparmurat Niyazov in 2006 also raised questions concerning the future direction of the country. Many saw this event as the opportunity for a radical adjustment of the Great Game going on in Central Asia over the access to natural resources. Yet the new government did not significantly alter the objectives of Turkmenistan.

Historical evidence tells us that rapid and profound changes at the top in producing countries have very rarely resulted in the disruption of natural gas exports. Bilateral gas contracts generally create favorable conditions for both parties and tend to be resilient in case of political instability.

1.3 Commercial Disputes

Commercial disputes have been the principal cause of disruptions of gas flows lately and should thus be considered one of the main risks for the EU. As a matter of fact, it is the only threat that has actually materialized and has caused insecurity in the recent past such as in the 2006 and 2009 Russia-Ukraine gas crises.

The political economy of gas trade gives the bargaining power first to the customer, but then the leverage shifts into the hands of the producing country, which knows that once the pipeline has been constructed, the funds already invested being extremely large, the customer needs a steady cash flow. Therefore, the customer needs the gas to keep flowing in and cannot afford a cut; it will thus accept an increase of the price asked by the producer.

Vernon,[5] and later Victor et al. (2003) have referred to this phenomenon as the "obsolescing bargain."[6] These authors list the risks embedded in the development of a cross-border pipeline project:

- The investment climate is the primary factor to be overviewed
- The involvement of a transit country can complicate the negotiations
- Gas infrastructure in the off-take markets needs to be sufficiently developed to allow a satisfactory off-take quantity to be introduced into the market and to render the pipeline profitable
- The off-take price of gas also needs to be competitive compared to incumbent fuels (such as coal or hydroelectric generating stations)
- Partner countries along the gas value chain profit from being linked to international institutions, which reduce the transaction costs and ease the

enforcement of the contracts. This can be seen as referring directly to the Energy Charter Treaty, designed to perform the mentioned tasks, but still not ratified by Russia.

1.4 Resource Nationalism

Every country in the world is indeed resource nationalist in the sense that it wants to harvest the most fruits out of its soil. The reality is that while in the past International Oil Companies (IOCs) could easily manage the rate of depletion of the fields they were operating and could easily prospect foreign territories, nowadays those prerogatives have fallen back in the hands of the national governments.

Some authors[7] have argued that the NOCs have different stakeholders from IOCs and, therefore, a different way of envisaging their activity. They play an important role in their domestic economies, need to satisfy actors other than international investors, and sometimes play the role of an instrument of foreign policy. The maximization of the benefits is consequently "one of the variables in the equation" and not the only one, which has led some to argue that NOCs take less efficient decisions than IOCs. This being said, the situation greatly varies depending on the country as each state has a specific attitude, some behaving in more efficient ways than others.

Resource nationalism is not different from any other foreign policy issue; countries protect their interests, like they always have. For example, Saudi Arabia directs gas to the production of chemicals and uses this resource to propel the industrialization of the country; therefore, it has no intention to export gas. Can this be called resource nationalism? It is rather the logical expression of a development strategy. The EU will have to deal with this like it would any other issue of international economics; resource nationalism per se should not be considered as a cause for heightened concern.

2.Risk Quantification by Source

As we have outlined the major geopolitical factors threatening the global natural gas industry, the discussion now needs to be focussed on the analysis of each major gas source so as to determine individual weaknesses and opportunities.

2.1. Russia

Russia is today the EU's largest external supplier of natural gas with about 196 bcm exported in 2008.[8] It is also the country possessing the largest reserves in the world (44.38 tcm), the second largest producer (527.5bcm) and the largest natural gas exporter.

Russia has been a reliable partner for its main clients for decades, and it is likely to remain one in the future. Historical experience shows that even during periods of heightened tensions between the West and the Soviet Union, supplies were not cut. In the recent past, three unfortunate incidents involving Europe's gas supplies occurred, which fuelled fears and motivated many to call for a reduction of the dependence on Russia and an increased quest for alternative sources, which led to the emergence of the Nabucco project.[9]

All Russian gas is exported by pipeline. This assures the customer at the end of the pipeline that the gas flow cannot be diverted easily and quickly. When political motivations are balanced by economic interests, the mutual dependence between Russia and the EU is a factor that limits, to a great extent, unilateral decisions. On the other hand, countries allowing the pipeline to go through their territories can exert pressure on either the producer or the customer. Therefore, Russia is a reliable partner over the long run, but can present significant risks in the short term, whether those risks are directly created by Russia or by third countries.

Russian gas export routes all point in the direction of Europe and are concentrated in Ukraine. The Ukrainian problem has motivated Russia to find new routes to reach West European markets. Both the Nord Stream and South Stream projects follow this logic.

The growing ties between Russia and China have been deemed to have the potential to divert gas flows away from Europe. Chinese energy needs have grown dramatically in the last few years, but the usage of natural gas remains relatively limited. However, several import projects have caught the attention of observers. For the small volumes imported until now, China has preferred the LNG option. Pipelines are now on the agenda, and a first link to import gas from Kazakhstan, Uzbekistan and Turkmenistan became operational in December 2009.[10]

It would take decades for gas flows towards China to equal those towards Europe. Russian gas exports to East Asia will continue and certainly expand, but Russia will be able to keep on supplying Europe and slowly expand its Asian markets.

Russia's internal situation and domestic market are likely to have more direct influence on gas supply issues than China. Indeed, Russia's available export surplus is determined by domestic political and social factors. Two major factors have broad implications for the security of European supplies: domestic prices and investments.

Gas prices in Russia are extremely low compared to export prices, about $43/1000 cm for industrial users and $32/1000cm for individual users[11] against around $275/1000cm on average in 2009 for Western Europe. Western European markets represent 70 percent of Gazprom's profits. Consequently, Gazprom is constantly pushing the government to increase domestic prices. The Russian government has promised to put industrial prices on par with export prices from 2011. The increase of prices for individual users is considered too politically sensitive and is likely to remain untouched in the near future.

If Russian industrial prices are increased, and the Russian domestic market liberalized, the consequences for Europe would be very important. First of all, many observers agree that it would force Russian industrial infrastructure to become more efficient. Therefore, if less gas is consumed domestically, Gazprom (which still holds the state monopoly on exports) would have larger surpluses for exports. Those could potentially momentarily offset the decrease of output due to the lack of investment.

Another consequence would be the end of friction between Russia and Central Asian producers. The latter would have no particular incentive to reach European markets if the Russian one offers a similar price level.

The second problem concerns the lack of investment in infrastructure and exploration. As Jonathan Stern recently underlined,[12] European gas demand has significantly decreased because of the crisis and is difficult to predict in the long run. Moreover, if supply capacity became tight, supplies to the Russian domestic market and exports to CIS countries would likely be reduced before exports to Europe. It is also important to notice that Russia has no interest in massive investments in new production facilities, because tight supply allows prices to be kept higher than if supply was abundant, and it gives Russia leverage when negotiating contracts. Moreover, Dasseleer (2008) even notices that a present abundant supply would promote short-term deals over long-term take-or-pay contracts. The uncertainty on the markets and the EU's insistence on diversifying its imports away from Russia does not favor accelerated investment; on the other hand, Russia has no particular interest in letting the situation deteriorate and thus risk being short of gas to fulfil its commitment in the future.

2.2. Nigeria

Nigeria is Africa's first oil producer and also possesses large gas resources (about 5.22 tcm of proved reserves according to BP, 2009). The gas produced so far has largely been flared because of the lack of the necessary infrastructure. Today the flaring rate reaches 40 percent of a production of about 35 bcm/yr; (this rate used to rise up to 75 percent a few years ago), which partly explains why Nigeria remains below its potential production capacity (35 bcm in 2008, while Egypt, for example, produced 59 bcm, according to BP).

The relative distance of Nigeria from its export markets requires that exports take the form of LNG. A pipeline project connecting Algeria and Nigeria is under study (Trans-Saharan Gas Pipeline) but is subject to too much geopolitical instability to represent a real step forward for the overall gas industry. As in many other oil- and gas-producing countries, the government aims at increasing the domestic consumption of gas as a means to kick-start the development of the country. Nevertheless, it is not certain that the state will have the capacity to do this on a large scale, as the country lacks the most basic infrastructure.

Nigeria possesses large gas reserves, but gas fields are quite scattered. This requires that important collection infrastructure is built. From the current 12bcm/yr, the potential domestic consumption could reach 35 to 40bcm/yr by 2030. The positive corollary of this rather low consumption for decades to come is that, providing appropriate investments are done, the production surplus that could be exported would be rather large.

In fact, the export potential could increase from a small 21bcm today to 100bcm by 2030. While the EU countries are likely to remain the main customers of Nigerian gas, the US also may become an important buyer. However, the previous arguments do not take into account the instability of the Nigerian political landscape. The area where most of oil and gas deposits lie, the Niger Delta, is plagued by constant unrest and violence since the Biafran war in 1967. Although the country's regulations offer interesting prospects for IOCs, the possibility for effective work is greatly hindered by local politics. The characteristics of Nigerian politics render the country a potentially unreliable supplier.

2.3 Norway

Norway has traditionally been a very important gas supplier to Europe. Although it is not part of the EU, it follows EU regulations and has proved a perfectly reliable partner for decades. Important resources are still to be extracted (3,000 bcm) and perhaps even discovered. However, the OME expects Norway's production to start declining after 2030. This constitutes a potential risk, as Europe is dependent on Norwegian gas.

2.4. North Africa

In a recent report, C. Spencer has drawn a portrait in which Maghreb countries were depicted as less reliable than commonly believed.[13] Internal politics and the emergence of terrorist groups create areas of tension detrimental to the economic development of the region. However, while many producing countries face internal problems, they have proved reliable suppliers of oil or gas for many decades. Therefore, any political analysis should be analyzed critically.

Spencer lists in particular three main threats common to Maghreb countries:

- Challenges to authoritarianism: Many political leaders have managed to secure life-long grip over power (through constitutional amendments in Tunisia and Algeria). The conjunction of poor economic performance and loss of aura gained during the decolonization period offers the possibility of social disturbances.
- Growth of Islamism and civil unrest: The failure of the governments to foster economic development through Western-imported models has permitted the emergence of groups calling for the regeneration of the society by Islamic values. These groups range from political formations to terrorist organizations such as Al-Qaeda in the Islamic Maghreb. The latter remains a minority fringe, but the wider movement has the capacity to be "gently subversive" and to push for a completely alternative way to organize society and politics.
- Economic weakness (distorted development): A very large fraction of the population of those countries is composed of children and young adults. In Morocco and Algeria, about 250,000 new job-seekers enter the work market each year and about 16 million jobs will need to be created by 2020 in the entire Maghreb region. If governments fail to do so, unemployment will certainly fuel social opposition to the established political order and encourage a growth in radical Islamic sentiment.

2.4.1 Algeria

Algeria possesses the 10th largest gas reserves with 4.5 tcm proved in 2008.[14] Those reserves are very large and concentrated in one field (Hassi R'Mel), while the rest of Algeria has remained largely under-exploited. New discoveries have been rare and have only allowed the compensation of gas already extracted, but more active prospecting and reduction of flaring could drastically augment future production from 90 bcm/yr today to about 180 bcm/yr by 2030, according to OME's projections.[15]

On the geopolitical front, the problem of the status of Western Sahara and the differences between Algeria and Morocco should not be considered an issue. Though the border has been closed since 1994 and relations between Algeria and Morocco can still be considered bad, it has never prevented the Maghreb-Europe pipeline (Pedro Duran Farell) from bringing gas to Spain. As of today, there is no reason why this would change.

A source of greater concern is the course taken by domestic politics. In fact, "the real security threats are not so much transnational as local and humans."[16] Algeria has known decades of instability caused by the post-independence institutional chaos and the struggle against Islamic groups such as the FIS (Front Islamic du Salut) and GIA (Groupe Islamique Armé) in the 1990s. This has weakened the country, although direct terrorist threats in the northern part of the country and in urban centres seem to have become more sporadic in the last few years.

In April 2009, President Bouteflika won the presidential elections for the third time. There is some concern owing to the fact that, to a large extent, the stability of the country is due to President Bouteflika's control of the government, and he will not be able to retain power forever.

If a radical Islamic political formation were to come to power in Algeria, the consequences on the management of mineral resources would be unpredictable.

This, however, remains a low-probability risk. The AQIM group has been at the center of much discussion, but the probability that it may undertake a major terrorist action against energy infrastructure remains limited.

Another uncertainty representing a risk for the future is the increasing domestic demand for gas that could upset export strategies. President Bouteflika's government wants to expand Algeria's domestic industrial capacity. Much of Algerian power generation comes from gas-fired stations, and the government has induced a switch from oil to gas consumption. If domestic consumption reaches 50 bcm/yr by 2030, as the OME forecasts, it is hoped that the necessary investments in new fields will be performed in time so that exports are not affected (180 bcm/yr expected by 2030). It must also be noticed that Algerian domestic demand may increase by 7.4 percent per year on average and would thus double by the end of the next decade (2018), according to a report from the Algerian Ministry of Energy and Mines presented on September 24, 2009.[17] Although it is doubtful that the country has the capacity to generate a growth rate capable of absorbing this increase, those figures nevertheless show the clear intention of the government to privilege domestic consumption of gas so as to maximize oil exports.

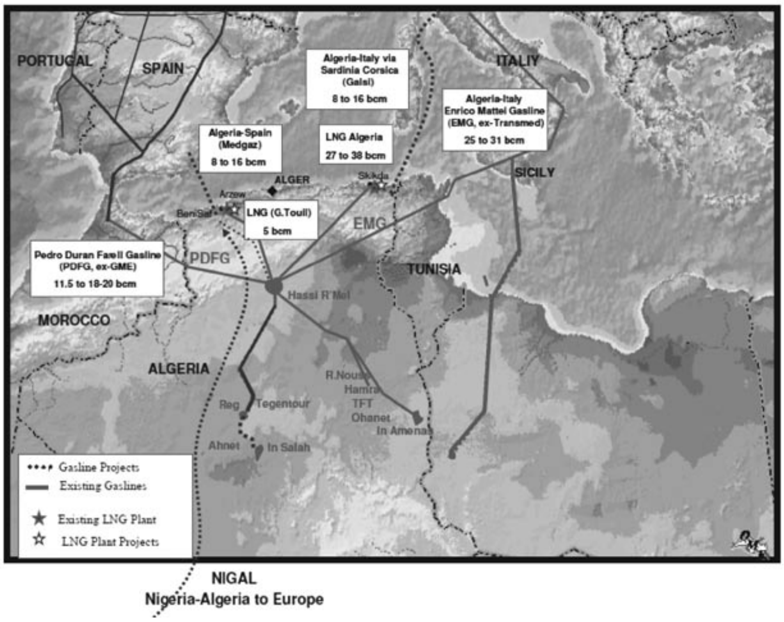
The recent Algerian call for the rapid establishment of a gas OPEC so as to increase gas prices is a further cause of concern. Algeria's former Energy and Mines Minister Chakib Khelil recently said that gas prices are "unjust" and should be "two times their current level."[18] He also called for a new gas pricing system. Also, experts from the Energy and Mines ministry have claimed that Algeria is committed to increasing the volume of gas being sold through short-term contracts or via the spot market. Two new LNG trains with a capacity of 9mn tons/yr will come on-stream soon, which will allow the volumes sold spot to double, from 10bcm/yr today to 20bcm/yr by 2012. The development of the new LNG terminals in Arzew and Skikda could be a signal that Algeria wants to diversify its exports destination in order to be less dependent on Europe.

However, facts tell us a different story. The construction of the Galsi pipeline, which will connect Algeria and Northern Italy (via Sardinia), and the impending entry into operation of the already-constructed Medgas pipeline will help to strengthen EU-Algerian relations.

2.4.2 Libya

For the moment, Libya is a relatively small supplier of gas. The country has put little effort in exploration and shown only limited interest in the gas business. Its reserves are smaller than Algeria's (1.5 tcm according to BP, 2009) but the country is also largely underexplored. The actual small production of 15 bcm/yr is expected to increase rapidly in the future and could reach 55bcm/yr by 2030.[19] In 2008, only 10 bcm were exported (Eurostat, EIA), and only two European countries, namely Italy and Spain, were supplied.

Figure 1. Actual and Future Maghreb Export Capacity to Europe



Source: OME Encouraged Del. 6 (2006)

On the overall energy security picture, therefore, Libya represents a limited risk and an important opportunity.

It must also be noticed that Libya's export capacity is small and consists of one gasification facility and one undersea pipeline (Greenstream). Libya also has a long experience with LNG technology as it historically was the second largest exporter after Algeria. All these factors allow us to conclude that Libya possesses a large potential that could certainly benefit EU's energy security. The government has shown clear interest in increasing gas production, especially for supplying the domestic market since much of the power generation is gas-fired, alongside developing an export strategy. Libya's population, at 6 million, is much smaller than Algeria's; consequently, even if the domestic consumption increases by 2030 – from 6 bcm/yr now to 12 bcm/yr then – the impact on export capacities will remain minor.

On the political side, the international situation of Libya has drastically improved since the lifting of EU and US sanctions in 2004. The largest risk comes from more internal factors and concerns the underdevelopment of government institutions and the total absence of an institutional framework for the succession to the colonel.

2.4.3 Egypt

Egypt is, for the moment, a very small supplier of gas (5.7bcm in 2007 to the EU out of a production of 58bcm), but its geopolitical interest is great. It possesses around 2.13tcm of proved reserves, and there could be some 3.3tcm still to be found. This would position Egypt as an even larger potential supplier than Libya. Conversely, Egypt's population is much larger than Libya's and when the OME predicts that Egypt's domestic gas consumption will reach 70bcm/yr in 2030, it leaves a much smaller share available for export. It is hoped that new fields coming on-stream will allow surplus volumes to grow in parallel with the domestic appetite. It must be noted that regulations require that a significant share of the reserves be left untouched. If production grows sufficiently to reach 120bcm/yr by 2030 (OME's projections), around 50bcm/yr would be available for exports. The short-term problem is that Egypt lacks the infrastructure for large-scale exports. Only two solutions are available: LNG or the Arab Gas Pipeline, which bypasses Israel. This pipeline could potentially fill up Nabucco, but the realization of such a scenario is still very vague, and Egypt alone could not sustain Nabucco.

2.5 The Fourth Corridor - Central Asia and the Gulf Region

The so-called fourth corridor could potentially pool the resources from several areas: the Caucasus (Azerbaijan), the Caspian basin countries (Central Asia and Iran), and the Middle East countries (Iraq, Egypt, and potentially, Qatar), thus acting as an alternative route allowing Europe to diversify away from Russia, Norway and the Maghreb.

The primary means of attracting those resources has materialized as the Nabucco pipeline. The pipeline, favored by the EU and the United States would rely, as of today, on Azeri production. Azerbaijan possesses the giant Shah Deniz field that could produce between 30 and

70bcm/yr by 2020. Even if only a fraction of this amount is devoted to export, this represents a very large potential supply for the EU and for the Nabucco pipeline. However, Shah Deniz will reach a plateau by 2020 and start declining afterwards. Moreover, Gazprom announced last April 2009 that it would start purchasing Azeri gas at European prices ($350/1000cm according to the newspaper *Kommersant*) in 2010. It is clear that this move is intended primarily at attacking the viability of Nabucco, as Russia used to be a supplier of gas to Azerbaijan, not vice versa. Consequently, Nabucco needs a much wider country base to be profitable. Moreover, the Gazprom's South Stream project connecting Russia to Bulgaria with a pipeline under the Black Sea is a serious threat to the completion of Nabucco, as two projects of large capacities in the region would be mutually exclusive.

The region has large reserves and a significant export potential, but the instability of the commitment of the most important potential suppliers as well as the potential competition to access those reserves significantly reduces its attractiveness. In terms of reserves, many of the countries presenting large potential are not the easiest to deal with, such as Iran, Turkmenistan and Iraq; Qatar, on the other hand, offers much more interesting perspectives.

2.5.1 The Caspian Basin and Central Asia: The New Great Game

In Central Asia, the most important resources are located on the Eastern side of the Caspian Sea (mainly Turkmenistan – and, in fact, mostly in Eastern Turkmenistan, close to the Afghan border). From there, only three routes can be taken to establish a link to Europe:

- through Russia, which makes no sense as it is precisely what the EU wants to avoid.
- through Iran, which would make much sense geographically and geologically, as the country possesses the second largest reserves in the world and a pipeline connecting southern Turkmenistan and Iran already exists; it was initially designed to supply gas to Iran and Turkey and later on to Europe. It was not completed not only because of the lower-than-expected Turkish natural gas needs but also because of Turkmenistan's lack of real commitment to any project bypassing Russia. Also, a major impediment resides in the well-publicized poor political characteristics of Iran and its difficult relations with the Western world. Although Europe would greatly benefit from Iranian gas, it seems politically unfeasible for the moment because of international sanctions on Iran (also threatening Western companies having activities in Iran) and because of manifest demonstrations of aggressiveness coming from the Iranian side.
- Directly across the Caspian Sea and into Turkey. This third route would be an effective alternative and could help materialize the hoped-for fourth corridor. It could, for instance, fill up Nabucco. But there are three reasons why the Trans-Caspian route is potentially hazardous. First of all, a pipeline under the Caspian Sea would need to be built, and this is impossible as long as the territorial status of the sea is not settled. Secondly, it crosses the Caucasus, which is far from being a model of stability. Finally, the reliability of the supply on the Turkmen and Kazakh ends is far from guaranteed. One could also add that the cost of the project would be prohibitive.

Concerning the legal status of the Caspian Sea, Bahgat (2007) writes:

"According to the United Nations Convention on the Law of the Sea, nations bordering a sea may claim 12 miles from shore as their territorial waters

Table 1: Greater Caspian Basin Proven Reserves

Proven Reserves at end 2008

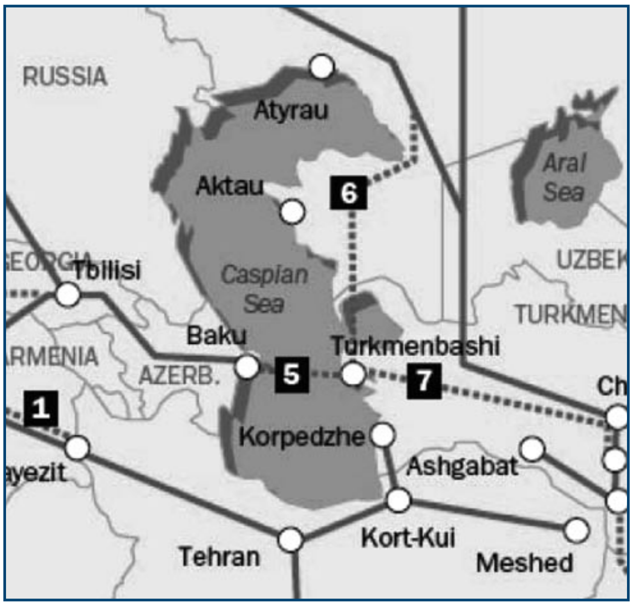
	Trillion cubic meters	Share of world total	Rank
Iran	29.61	16.0%	2
Turkmenistan	7.94	4.3%	4
Iraq	3.17	1.7%	12
Kazakhstan	1.82	1.0%	18
Uzbekistan	1.58	0.9%	21
Azerbaijan	1.20	0.6%	25

Source: BP 2009

and beyond that a 200-mile exclusive economic zone (EEZ). If the Law of the Sea convention were applied to the Caspian, full maritime boundaries of the five littoral states bordering it would be established based upon an equidistant division of the sea and undersea resources international sectors. If the Law were not applied, in other words if the basin is considered a lake, the Caspian and its resources would be developed jointly – a division referred to as the condominium approach. After more than a decade since the breakup of the Soviet Union, the five littoral states have not agreed on whether to characterize the Caspian as a sea or a lake."[20]

Russia favors the median line solution where the Caspian Sea is divided according to a line running across the seabed at the same distance from both opposite shores. Russia, Kazakhstan and Azerbaijan have already agreed (in 1998 and 2001) to divide the Northern part of the Sea based on this criterion. Iran presents a roadblock as it demands that the Sea be divided equally between every coastal country (20 percent of the sea surface and seabed for each of them). Finally, what is most important for the purpose of building the Trans-Caspian Pipeline is an agreement between Turkmenistan and Azerbaijan as the pipe would connect those two countries. They have agreed that the section of the Sea shared between them should be divided according to the median line principle, but they have disagreed on the exact position of that line.

Figure 2. Major Caspian Existing and Potential Pipelines



Source: Platts (cited in chapter 5.2.3)

Consequently, it must be remarked that there is no viable solution to fill in Nabucco in Central Asia and over the short term. From that perspective, a pipeline originating from the Gulf and reaching Turkey directly could be a satisfactory solution.

- In the perspective of the Gulf countries, a last solution to create the fourth corridor is through Iraq and Turkey.

Central Asian resources were not used to their maximum potential due to the inclusion of those countries in the Soviet Union. The disintegration of the USSR has, so to speak, brought those resources to a market in need of an alternative to the Middle East concerning oil and to Russia concerning gas. It is therefore logical that this attracted the attention of all the surrounding powers. First of all, Russia still has very strong ties in the region and has the advantage of being connected to those countries by the Soviet gas network. Presidents Vladimir Putin and then Dmitry Medvedev have been active in strengthening these ties. Secondly, Europe sees Central Asia as a means to reduce the dependence on Russia. Finally, China could tap Eastern Siberian reserves; but China is unlikely to accept being dependent on Russia. Therefore, it will try to access Central Asian resources. Central Asian countries represent a potential for new diplomatic ties for Beijing and they offer China the possibility to create a sort of buffer zone on its Western border.[21] In any case, China is slowly extending its network in the region and has increased trade with those countries in the past years. The Turkmenistan-China pipeline has been completed and is now operational and connects Kazakhstan, Uzbekistan and Turkmenistan to China. There is no reason that the project will not be fully implemented, and it could allow the supply of up to 40bcm/yr of gas to China in a few years.

Therefore, one realizes that Central Asian countries can play three games, with three different actors. It would be a mistake to see those countries as flexible and powerless as they were right after the events of 1991. The simple fact that Russia and China have started an upward move regarding the prices they offer for Central Asian gas proves that both Kazakhstan and Turkmenistan will take advantage of their position to maximize the revenues from their natural resources. Despite European and American eagerness to open up the region, the physical and geopolitical variables at play seem to have established a tripartite game between China, Russia and the Central Asian states, thus excluding European interests. The successful completion of a Trans-Caspian pipeline or Iranian bypass could change the nature of the game and increase the attractiveness of European markets; but the pre-requisite for these solutions to be implemented is that Central Asian countries commit themselves to directly supplying the West. This is a vicious circle, from which an exit remains distant.

Turkmenistan embodies the major difficulties inherent in dealing with Central Asia. Any pipeline aiming at bypassing Russia would necessarily enter into direct competition with the Central Asian Center transmission system inherited from the Soviet period. For such a project to receive the green light, it would need to be profitable. For Turkmenistan, it would mean the disadvantage of having to pay for it, while the pipeline to Russia already exists and is amortized; but, at the same time, the project would also present it with the advantage of avoiding Russian intake prices and transit fees and supplying end markets directly. For the partner company or country, it presents the disadvantage of having to fund an extremely expensive project and not being sure that Turkmenistan will fully respect its commitments.

Moreover, Russia and Turkmenistan have apparently solved their disputes over prices for the time being, and Russia probably acknowledges the importance of remaining the principal buyer of Turkmen gas. Under those circumstances, the prospects of connecting Turkmenistan more directly to Southern Europe and the Balkans seem significantly compromised. This is even truer since a new and cheaper export destination has opened eastward, in China.

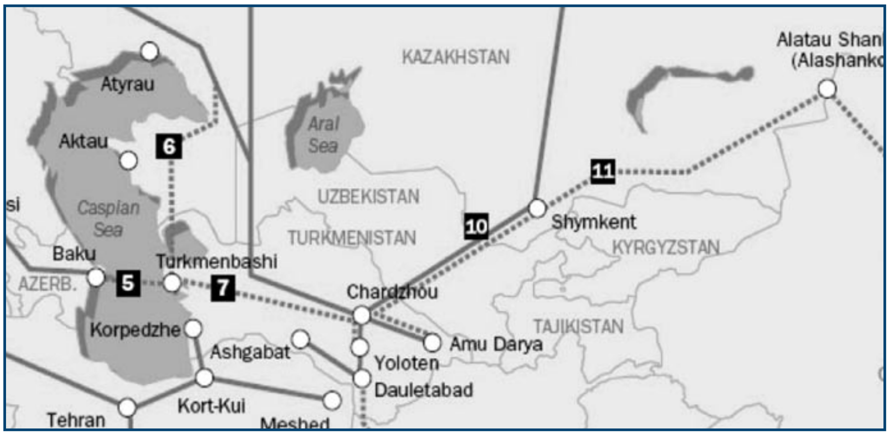
3.The Gulf and the Security of Europe's Gas Supplies

The Gulf region holds the largest gas reserves in the world, is significantly unexplored (concerning gas), and its gas resources lie geographically closer to Europe than Russian resources. Gulf countries could become the major source of supply for a potential fourth corridor and for filling up Nabucco, if dealing with Central Asia proves unsuccessful for the EU. Unlike Central Asia, Gulf countries enjoy easy access to the high seas and are not constrained with previously existing infrastructure; transit risks are thus much smaller than for other regions. Moreover, gas is generally found in large deposits thus making the extraction much easier than in countries such as Nigeria. On the other hand, in terms of economic and political characteristics the countries of the region – both those with major export potential and those whose resources are limited – differ substantially.

Iran and Qatar possess the world's second and third largest reserves, respectively; Saudi Arabia, the UAE and Iraq also possess large reserves. Despite promising prospects, Gulf countries offer mixed insights concerning export potentials and geopolitical stability. Three variables can be highlighted:

- Domestic consumption
- Internal political stability
- Foreign relations stability

Figure 3. The Future Turkmenistan-China Pipeline



Source: Platts (cited in Chapter 5.2.3)

Only countries which respond positively to these three criteria may be considered potentially important future supply sources.

Domestic consumption will be the primary factor that will determine the volumes of natural gas available for export by the Gulf countries and will certainly constrain future exports. Countries with significant oil production – such as Saudi Arabia, the UAE and Iran – or wishing to develop domestic industries (petrochemicals) and infrastructure (power plants and desalination facilities) will use gas either to re-inject it in oil fields or as a substitute to oil for the domestic economy. Consequently, the share of gas available for export could be extremely low (close to 20 percent, if not less). Saudi Arabia, in particular, could be an important exporter of gas but has a policy to reserve gas for domestic consumption.

Other producers from the Gulf, such as Kuwait and Oman, have produced limited quantities of gas so far and are not likely to become major exporters.

Political instability is the greatest in Iraq and Iran. Iraq is just slowly coming out of a seven-year war and is as far as a country can be from being a stable state presenting the attributes of a solid government and a unified population. As noted by Stansfield:[22]

> Iraq has fractured into regional power bases. Political, security and economic power has devolved to local sectarian, ethnic or tribal political groupings. The Iraqi government is only one of several 'state-like' actors. The regionalization of Iraqi political life needs to be recognized as a defining feature of Iraq's political structure.

Table 2. Gulf Countries' Proven Reserves

Natural gas: Proved reserves	at end 2008	
	Trillion cubic metres	Share of world total
Iran	29.61	16.0%
Qatar	25.46	13.8%
Saudi Arabia	7.57	4.1%
United Arab Emirates	6.43	3.5%
Iraq	3.17	1.7%
Kuwait	1.78	1.0%
Oman	0.98	0.5%
Yemen	0.49	0.3%
Bahrain	0.09	

(Source: BP 2009)

Moreover, the recent departure of US troops from the Iraqi soil is in itself a supplementary cause for concern, as this event could lead to even more instability.

Oil production in Iraq is unlikely to reach the levels prevalent under the Saddam Hussein regime any time soon. This applies to gas even more because of the higher complexity of the infrastructure required. Nevertheless, Iraq should not be dragged out of the natural gas geopolitical map, as the northern side of the country (Kurdistan) enjoys a certain degree of autonomy and could reach a higher level of oil and gas productivity than the rest of the country. Kurdistan could be seen as one of the major suppliers of the Nabucco project.

Moreover, from a Gulf perspective, Iraq is the shortest land route towards Turkey and Europe. Relying on a pipeline linking Qatar to Turkey through Iraq seems an unwise prospect over the short term because of the insecure environment in Iraq; but this solution must not be discarded though its potential implementation will depend on the political evolution of the region.

It is difficult to foresee the evolution of Iran, but although the country experienced episodes of violence and social unrest recently, after the contested re-election of President Mahmoud Ahmadinejad, the regime holds the reins of power firmly and it is difficult, although not impossible, to foresee a drastic alteration of its policy.

What is more important than the protests in the streets of Tehran are the power games played behind the scenes between the clerical leaders, opposition parties and the leader of the Expediency Discernment Council (Akbar Rafsanjani). These actors have often supported diverging views and policies which have prevented major advances from taking place. Instead, in most cases, these differences have led to stalemates and prevented the development of major infrastructure, with the paradoxical consequence that Iran has failed several times to honor its commitments in gas-exporting projects.

Gas exports from Iran remain controversial and a strong current exists in the Iranian Majlis

(Parliament) which favors the use of gas exclusively for domestic consumption. While the government authorities officially favor export projects and ostensibly promote them, in fact the only operational export project is the pipeline to Turkey, which has witnessed throughput shortfalls in winter, when gas is required by the domestic Iranian market.

On the foreign relations side, Iran is in a difficult situation because of the nuclear issue. The enrichment of uranium and its potential military use are posing a great obstacle for Iran in the international arena. The hardline leadership of the country shows little signs that its position concerning the dossier will change in the near future, and a hypothetical invasion by foreign troops would be the worst case scenario concerning gas infrastructure. Consequently, Iran is not officially considered by the EU as a candidate for filling up Nabucco.

To sum up, both Iran and Iraq are places where investments in the energy sector, and gas in particular, seem currently difficult; but the geographical positions of those two countries, which share a border with Turkey, and their very large resources, place them in a "hardly avoidable category" as future suppliers of gas to the EU. There is no easy solution to this dilemma, but if European needs increase, and if a certain diversification is to happen, these two countries are likely to become necessary partners in a medium- to long-term perspective.

Today, the only country in the region presenting stable political characteristics with low oil production and a small population is Qatar. Qatari production and exports keep increasing, and the OME predicts a marketed production as high as 200 bcm by 2020 and 300 bcm by 2030. Qatar uses LNG as its export vehicle; this means that potential supplies to Europe would be in relatively high competition with Asian and North American demands due to the flexibility of LNG exports.

Nevertheless, Europe is likely to remain the major importing market for natural gas in the world, which should attract the attention of producing countries. Moreover, Europe imports very limited amounts of Qatari gas for the time being (7.9 bcm in 2009, according to BP), which goes to Spain, Belgium, the UK and Italy. Qatar represents a very important opportunity for diversification of European gas supplies, and it presents very limited geopolitical risks. Even if competition is fierce, in absolute figures an important quantity of gas could be allocated to Europe and specifically to countries which still lack diversification possibilities (such as Poland, which is expected to start importing from Qatar very soon, and Greece). Qatar is, therefore, considered a strategic future supplier of gas to the EU.

4. The Increase of LNG Trade

Currently, LNG represents about 30 percent of total gas trade, but the proportion is likely to increase as LNG transportation costs decrease. The higher flexibility of gas shipments would have several impacts. It would, for example, allow the emergence of a more important spot market for gas. At present, only a few places play this role (mainly the Henry Hub in the US, the National Balancing Point in the UK, and Zeebrugge on continental Europe), but if the roles of the European hubs increase, they would acquire acceptance as price discovery tools. A gas spot market would probably augment the volatility of prices and could both reduce security of supply and play the role of an emergency tool.

Gas prices are for the moment pegged to oil prices because gas contracts are bilateral and infrastructure is fixed, which makes gas an illiquid asset. However, Jonathan Stern (2007) has argued that the link between oil and gas is becoming less relevant because switching capacity in power generation facilities is increasingly being abandoned.[23] Therefore, using oil to price gas is going to be more a matter of strategy and politics rather than a physical necessity.

Facilitated competition for gas between various actors may be brought about by an increase of LNG trade involving Europe, North America and East Asia. For example, Qatar will serve both the Atlantic basin and the Pacific basin, while Trinidad and Tobago will play the arbitrage between North America and Europe. Algeria and African exporters, primarily Nigeria, could also divert some of their exports to the US.

Although the long-term trend points to LNG taking a growing share of gas trade, future global gas requirements are very difficult to predict. The development of Alberta tar sands would require extensive use of Canadian gas, which would subsequently not be available for export to the US. On the other hand, the US possesses very large unconventional gas reserves. As the IEA notes: "In the reference scenario, unconventional gas output worldwide rises from 367 bcm in 2007 to 629 bcm in 2030, with much of the increase coming from the United States and Canada. The share of unconventional gas in total US gas production rises from over 50% in 2008 to nearly 60% in 2030."[24]

If the US starts producing such large volumes of unconventional gas, its need for imported LNG would be much lower. China's and India's needs also are difficult to predict. It is therefore not certain that the gas market will favor sellers in the future, and it is also not certain that the increase of LNG trade will bring competition detrimental to European energy security. LNG transportation costs will never be as low as for oil, and regasification plants are still relatively few (although this is about to change).

The gas market will most probably continue to primarily use long-term contracts in order to share the heavy upstream investment costs between the producer and the customer. Nevertheless, short-term contracts and spot sales will have growing importance in satisfying marginal changes in the demand/supply relationship. LNG will also allow for a greater fluidity of the market and allow the EU to partially diversify its sources by tapping exporters inaccessible by pipelines. Concerning geopolitical issues, LNG is not fully risk-free. The entire transportation chain could be threatened by terrorist acts and the explosion of a regasification plant could have a very negative influence on the public perception of this energy source. Maritime routes also present certain risks. However, the probabilities of such events remain small, and even if one occurred, its consequences would be minor for global trade.

The role of LNG is growing in Europe and regasification capacities are expanding, with new plants currently being built in Spain, Italy, the Netherlands and Sweden and more proposed in almost all European countries possessing a coastline (Germany, the Balkans, France, UK, Ireland, Lithuania, Romania, and Ukraine).[25] This means that the willingness to import more LNG is present in Europe; among other factors, the need for increased flexibility is a major determinant of this trend. Also, LNG must be seen by the EU as a way to increase security of supply in countries poorly linked to the main network (Baltic States and Balkans). In particular, Greece has recently shown interest in increasing the capacity of the Revithoussa regasification plant, in order to become a hub for supplying gas to the rest of the region (notably, Bulgaria and Serbia). Producing countries such as Qatar should view this as a positive sign that LNG is an energy source that will grow in the coming years and that, despite the buyer's market experienced currently, is certainly worth being developed.

To sum up, LNG will hardly become a major geopolitical risk and, while it is not a panacea, will provide additional security of supply for EU countries by offering some diversification possibilities. It could also offer leverage for those countries to counter the dominant attitude of producer and transit countries, in case the latter fail to honor their engagements or try to take advantage of their position.

5. Unconventional Gas

Unconventional has been one of the hottest topics in the gas industry in recent years. Unlike conventional gas, which is gas that has been trapped in large pools by impermeable rock, unconventional gas can be divided into four different types:

- Tight Sands Gas – formed in sandstone or carbonate.
- Coalbed Methane (CBM) – formed in coal deposits.
- Shale Gas – formed in fine-grained shale rock (called gas shales)
- Methane Hydrates – a crystalline combination of natural gas and water

The breakthrough of new technology in the US, which has led to massive increases in the production of unconventional gas, has already had significant impact on the EU gas market via world LNG trade flows and spot market prices for gas.

The increase in US indigenous production has led to a change in worldwide LNG trade flows in the few last years. European gas spot market prices have decoupled from oil and pipeline gas prices.

Lower spot market prices in the EU led to a temporary change of Russian long-term contracts: a 15 percent gas-to-gas price component in the long-term contracts was introduced and will be valid for three years. The decoupling of gas prices is due to the economic and financial crisis and the decline in gas demand, not just to changes in LNG flows.

With the decline in LNG demand in the US, more LNG has found its way to the EU. The decrease in US demand, in combination with the fact that additional liquefaction capacity has come online from Qatar and elsewhere in the same period, has encouraged EU gas importers to increase LNG purchases. This results in increased diversification of EU imports and increases flexibility, facilitating the replenishment of gas storage after the very cold winter of 2009. LNG imports into the EU increased by 26 percent, from around 50 bcm in 2008 to 63 bcm in 2009. This happened despite an overall decrease of 6 percent in EU natural gas demand.

In short, unconventional gas has increased world gas reserves and production, and LNG has allowed regional developments to impact the world gas market. Regardless of whether the EU will be able to replicate the production revolution witnessed in the US, the increasing supply of unconventional gas has already had significant influence on the world gas market and thus on the EU, where it has put a downward pressure on gas prices. However, if unconventional gas turns into a waiting game for global gas investments, then this could lead to a serious security of supply threat because of the long lead-times for gas infrastructure projects.

5.1 Unconventional Gas Reserves in Europe[26]

Currently, Europe has an estimated 5.4 tcm (trillion cubic meters) of proven reserves enough to meet approximately 10 years of EU consumption. When it comes to unconventional gas resources, these reserves become significantly higher as total resources are estimated at approximately 35 tcm for Europe. Gas recovery rates vary from around 8 to 30 percent, but this could increase to approximately 40 percent with a production cost of around $100 to $300 per 1000 m3 in the long run, according to IEA estimates. At recovery rates of 40 percent, this would mean an increase in European gas reserves from 5.4 TCM to 19.4 tcm.

Assuming an annual indigenous European production (EU and Norway) of 300bcm per year, we can assume that indigenous European production, at 300bcm per year, could be extended from 18 years to 65 years. Assuming a less optimistic recovery rate of 25 percent would increase European reserves by 8.75bcm, increasing the current R/P ratio from 18 years to 47 years. This would have a considerable effect on security of supply in the EU, but whether the US experience can be replicated in the EU is subject to a number of uncertainties.

Very little is known about potential costs, environmental impact and the legislative framework of unconventional gas production. Environmental and legal issues may significantly hinder the production of shale gas in Europe. Europe has a more stringent legislation, a different geography and a much higher population density.

Unconventional gas production, know-how and technology have so far been limited to the US. Although major consolidation has taken place in recent years, whereby international oil and gas companies have acquired unconventional gas firms, the transfer of this know-how to the EU and the rest of Europe has not yet begun. Critical technology know-how includes horizontal drilling and hydraulic fracturing, which are key techniques to be mastered in order to make unconventional gas economically viable and to ensure that underground aquifers are not contaminated.

Finally, the connection of unconventional gas production to the EU gas grid is also an issue of uncertainty.

Table 3: Aggregate Measure of Risk by Rating Source and Transit Risks of the Producer Countries

Country	Source risk	Transit risk	Total risk
Algeria	medium	low	low
Azerbaijan	low	medium	medium
Central Asia (Turkmenistan, Kazakhstan, Uzbekistan)	medium	very high if via Iran	high
		high if via Russia	high
		high if via Trans-Caspian	high
Egypt	low	low	low
Iran	very high	medium if via Turkey	high
		low if LNG	high
Iraq	very high	medium if via Turkey	high
Libya	low	very low	low
Nigeria	very high	low if LNG	medium
		very high if via Trans-Saharan	very high
Norway	very low	very low	very low
Qatar	very low	low	very low
Russia	low	high if no change	medium
		medium if either Nord Stream or South Stream or both are completed	medium
Trinidad and Tobago	very low	low	low

Source: SECURE project calculations

broad terms, EU's principal suppliers can be considered safe partners. Transit risks, on the other hand, are much trickier to handle. They have been the cause of the most important concerns in the past years and are a direct consequence of the physical nature of gas trade.

The SECURE project has proposed an aggregate measure of risk by rating source and transit risks of the producer countries. A 5-point scale – ranging from very low, low, medium, high to very high – has been used to measure risk, and the outcome is summarized in Table 3.

As can be seen, Qatar offers all the advantages one could hope for, and increasing imports from there, if possible on the basis of long-term contracts, could bring both diversification and security.

It is thus important to stress that Qatar should play a more important role as a supplier of gas to the EU in the future as it would increase diversification and increase the overall security of supply due to the low risk linked with this country. The rest of the Gulf region presents diverging prospects as the majority of countries are not gas exporters and do not intend to become so. Despite political and security difficulties, Iran and Iraq have huge gas reserves, and it will be increasingly difficult to neglect these countries if the gas consumption in the world, and in Europe in particular, keeps growing as forecast.

Summary and Conclusion

This chapter has detailed the different geopolitical risks that could threaten future gas supplies to EU countries. It has first dealt with theoretical risks and then detailed risks on a country by country basis.

There are two major types of risks, which need to be taken into account: source risks and transit risks. Source risks comprise armed conflicts, coups d'etat, social disorder and so-called resource nationalism. In general, it appears that those risks remain rather low in countries which already supply the EU, except in a few cases such as Nigeria. In

Endnotes

1. European Commission, Green Paper, "A European Strategy for Sustainable, Competitive and Secure Energy," 2006.
2. Victor et al, 2006.
3. D. Jordan, J. Kiras, D. Lonsdale, I. Speller, C. Tuck, and C.D. Walton, *Understanding Modern*

Warfare (Cambridge University Press, 2008).

4. A. Aissaoui, *Algeria: the Political Economy of Oil and Gas* (Oxford: Oxford University Press, 2001).
5. R. Vernon, *Sovereignty at Bay: The Multinational Spread of US Enterprises* (New York: Basic Books, 1971).
6. Victor D., M. Hayes, "Natural Gas and Geopolitics: From 1970 to 2040," Stanford University Program on Energy and Sustainable Development Working Paper 8, 2003.
7. The Baker Institute, "The Changing Role of National Oil Companies in International Energy Markets Series," Available online at http://www.bakerinstitute.org/programs/energy-forum/publications/policyreports.html. Accessed February 9, 2010.
8. Eurostat Database, 2009, available at http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home
9. Nabucco is a pipeline project promoted by the European Union and linking Turkey to the Balkan peninsula and then continuing to Central Europe and Austria.
10. *MEES*, various issues.
11. P. Dasseleer, "Gazprom: L'idéalisme Européen à l'épreuve du réalisme russe,"Paris: L'Hartman Laserre, 2008.
12. J. Stern, "Future Gas Production in Russia: Is the Concern about Lack of Investment Justified?" Oxford Institute of Energy Studies NG 35, 2009.
13. C. Spencer, "North Africa: The Hidden Risk to Regional Stability"The Chatham House Briefing Paper, April 2009.
14. BP, *Statistical Review of World Energy*, 2009.
15. Observatoire Méditerranéen de l'Energie (2009): "Natural Gas Supply, Reserves, Production, Transportation and Transit". Deliverable 5.2.3 SECURE project
16. C. Spencer, "North Africa: The Hidden Risk to Regional Stability," The Chatham House Briefing Paper, April 2009.
17. *MEES* 52 (no. 42), October 19, 2009.
18. *MEES* 45 (no. 9), November 2009.
19. Observatoire Méditerranéen de l'Energie, "Natural Gas Supply, Reserves, Production, Transportation and Transit," Deliverable 5.2.3 SECURE project, 2009.
20. G. Bahgat, "Prospects for Energy Cooperation in the Caspian Sea," *Communist and Post-Communist Studies* 40: (2007): 157-168.
21. T. Kellner, "L'Occident de la Chine: Pékin et la nouvelle Asie Centrale (1991-2001)," Paris : Presse Universitaire de France, 2009.
22. G. Stansfield, "Accepting Realities in Iraq," The Chatham House, Middle East Programme Briefing 07/02, 2007.
23. J. Stern, "Is there a Rationale for the Continuing Link to Oil Product Prices in Continental European Long-Term Gas Contracts," Oxford Institute for Energy Studies, April 2007.
24. International Energy Agency, *World Energy Outlook 2009*, OECD, IEA: Paris, 2009.
25. Gas Infrastructure Europe database, 2010 Gas LNG Europe Dabase: http://www.gie.eu/maps_data/lng.html
26. Taken from SECURE deliverable 5.2.7 written by Ramboll.

References

- Aissaoui, A. 2001. Algeria: the political economy of oil and gas. Oxford: Oxford University Press.
- Avioutskii, Viatcheslav. 2003. Confessional geopolitics in southern Russia and in the North Caucasus. In *Central Asia and Caucasus Press*. Available online: http://www.ca-c.org/journal/eng-05-2003/01.aviprimen.shtml. Accessed February 9, 2010.
- Bahgat, G. 2007. Prospects for energy cooperation in the Caspian Sea. In *Communist and Post-Communist Studies* 40: 157-168.
- BP. 2009. Statistical review of world energy. Available at http://www.bp.com/productlanding.do?categoryId=120&contentId=7047744. Accessed February 9, 2010.
- Bruce, C. 2005. Friction or fiction? The gas factor in Russian-Belarusian relations. Russian and Eurasia Programme Briefing Paper 05/01, Chatham House.
- Cedigaz website: http://www.cedigaz.com/
- Center for Systemic Peace. 2009. War list data set. Available http://www.systemicpeace.org/warlist.htm. Accessed February 9, 2010.
- Chegrouche L. 2009. L'échiquier transsaharien: Potentiel de réserves et projets de transport. In *Medénergie* vol. 30 (September).
- Commission of the European Communities. 2009. Proposal for a regulation of the European Parliament and of the Council concerning measures to safeguard security of gas supply and repealing Directive 2004/67/EC.
- Commission of the European Community. 2006. Green Paper. A European strategy for sustainable, competitive and secure energy. Brussels, March 8.
- Dasseleer P. 2009. Gazprom: L'idéalisme Européen à l'épreuve du réalisme russe. Paris: L'Hartman.
- Egging R., S. Gabriel, F. Holz, J. Zhuang. 2008. A complementarity model for the European natural gas market. In *Energy Policy* 36: 2385–2414.
- Energy Information Administration, http://www.eia.doe.gov/
- Euronews. 2009. Russia, Turkey sign South Stream pipeline deal. August 7, 2009. Available http://www.euronews.net/2009/08/07/russia-turkey-sign-south-stream-pipeline-deal/. Accessed February 9, 2010.
- European Commission Staff Working Document. 2009. The January 2009 gas supply disruption to the EU: An assessment. COM 2009 (363).
- Eurostat Database. 2009. http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home
- Geopolitis. 2009. Al-Qaida au Maghreb Islamic. (12.06.2008). Available at http://www.tsr.ch/tsr/index.html?siteSect=327200. Accessed February 9, 2010.
- Hashimoto K., J. Elass, S. Eller 2004. Liquefied natural gas from Qatar: The Qatargas project. Baker Institute Geopolitics of Gas Working Paper Series.
- Hotelling H. 1931. The economics of exhaustible resources. In *Journal of Political Economy* 39: 137-175.
- International Energy Agency. 2009. World energy outlook 2009. OECD, IEA: Paris
- Jordan, D., J. D. Kiras, D. J. Lonsdale, I. Speller, C. Tuck, C.D. Walton. 2008. *Understanding modern warfare*. Cambridge University Press.
- Katz, M. 2007. Russia and Algeria: Partners or competitors? In *Middle East Policy* XIV, no. 4 (Winter).

- Kaufmann D., A. Kraav, M. Mastruzzi. 2009. Governance matters VIII: Governance indicators for 1996-2008.
- Kellner, T. 2009. "L'Occident de la Chine: Pékin et la nouvelle Asie Centrale (1991-2001). Paris : Presse Universitaire de France.
- Konoplyanik, A. 2005. Russia-EU Summit: WTO, the Energy Charter Treaty and the issue of energy transit. In *International Energy Law and Taxation Review* 2: 30-35.
- Konoplyanik A., Wälde T. 2006. Energy Charter Treaty and its role in international energy. In *Journal of Energy and Natural Resource Law* 24, no. 4.
- Le Courrier International. 2009. "Le gazoduc South Stream devient prioritaire'' 23.10.2009. Available at http://www.courrierinternational.com/breve/2009/10/23/le-gazoduc-south-stream-devient-prioritaire. Accessed February 9, 2010.
- Le Monde Diplomatique maps. Available at http://www.monde-diplomatique.fr/cartes/
- *MEES* 52, no. 33 August 17, 2009.
- *MEES* 52, no. 34, 24 August 2009.
- *MEES* 52, no. 42, October 19, 2009.
- *MEES* 52, no. 45, November 9, 2009.
- Nord Stream AG, http://www.nord-stream.com/en/
- Observatoire Méditerranéen de l'Energie. Natural gas supply, reserves, production, transportation and transit. Chapter 5.2.3 SECURE project.
- Petrosyan, K. 2003. What are the constraints on associated gas utilization? University of Dundee Working Paper. Available online. Accessed February 9, 2010.
- http://www.dundee.ac.uk/cepmlp/car/html/car8_article19.pdf
- PFC website, http://www.pfcenergy.com/default.aspx
- Pifer, S. 2009. Ukraine's geopolitical choice, 2009. In *Eurasian Geography and Economics* 50, no. 4: 387–401.
- Pirani S., J. Stern, K. Yafimava 2009. The Russo-Ukrainian gas dispute of January 2009: a comprehensive assessment. Oxford Institute for Energy Study.
- Protasov, P. 2009. Long-term modeling of resilience and flexibility of European Gas Transportation System: Integrated factors. ENERDAY proceedings, April 3, Dresden.
- Spencer, C. 2009. North Africa: The hidden risk to regional stability. The Chatham House Briefing Paper, April.
- Stern, J. 2007. Is there a rationale for the continuing link to oil product prices in Continental European long-term gas contracts. Oxford Institute for Energy Studies, April.
- Stern, J. 2009. Future gas production in Russia: is the concern about lack of investment justified? Oxford Institute of Energy Studies NG 35.
- Stansfield, G. 2007 Accepting realities in Iraq. The Chatham House, Middle East Programme Briefing 07/02.
- Tekin, A. and P. Williams. 2009. Europe's external energy policy and Turkey's accession process. In Center for European Studies Working Paper Series no. 170.
- The Baker Institute. 2007. The Changing Role of National Oil Companies in International Energy Markets Series. Various articles. Available online: http://www.bakerinstitute.org/programs/energy-forum/publications/policyreports.html Accessed February 9, 2010.
- *The Financial Times*. 2006-2007. Various articles.
- The International Energy Agency. 2009. *World energy outlook* 2009. Available at http://www.

worldenergyoutlook.org/docs/weo2009/WEO2009_es_english.pdf . Accessed February 9, 2010.
- The Petroleum Economist. 2007. Security trends in high-risk countries: Nigeria. London, September.
- The World Bank. 2009. Worldwide governance indicators 1996-2008. Available at http://info.worldbank.org/governance/wgi/worldmap_start.asp?allcountries=1. Accessed February 9, 2010.
- UN Comtrade, http://comtrade.un.org/
- Uppsala Conflict Data Program. 2008. Map of the world's conflicts in 2008. Available at http://www.pcr.uu.se/research/UCDP/graphs/charts_and_graphs.htm. Accessed February 9, 2010.
- Uppsala Conflict Data Program. 2009. Dyadic data set 2009.
- Uppsala Conflict Data Program. 2009. Non-state conflict data set 2009.
- Uppsala Conflict Data Program. 2009. One-sided violence conflict data set 2009.
- University of Texas. Perry-Castañeda library map collection. http://lib.utexas.edu/maps/commonwealth/ethnocaucasus.jpg
- Urs, Gerber. 2004. Wither South Caucasus: to prosperity or to conflict. In *The Caspian: politics, energy and security*, eds. Shirin Akiner, 323-342. Abingdon: Routledge.
- Vernon, R. 1971. *Sovereignty at bay: The multinational spread of US enterprises.* New York: Basic Books.
- Victor D., A. Jaffe, M. Hayes. 2006. *Natural gas and geopolitics: from 1970 to 2040*, eds. David G. Victor. Cambridge: Cambridge Univ. Press.
- Victor D., M. Hayes. 2003. Natural gas and geopolitics: From 1970 to 2040. Stanford University Program on Energy and Sustainable Development Working Paper 8.
- Victor D., N. Makarova. 2004. The Belarus connection: Exporting Russian gas to Germany and Poland. The Baker Institute Geopolitics of Natural Gas Studies Working Paper 26 (May).
- Vzgliad. 2009. Yuzhni Potek (Южный потек). October 22, 2009. Available at http://www.vz.ru/economy/2009/10/22/340726.html. Accessed February 9, 2010.
- Whist, S. 2008. Nord Stream: Not just a pipeline: An analysis of the political debates in the Baltic Sea region regarding the planned gas pipeline from Russia to Germany. Fridtjof Nansen Institute. Available at http://www.isn.ethz.ch/isn/Digital-Library/Publications/Detail?id=94432%26lng=en Accessed February 9, 2010.
- Winrow, M. 2009. Problems and prospects for the fourth corridor: The positions and role of Turkey in the gas transit to Europe. Oxford Institute for Energy Studies, June.

Overview of RES Characteristics and Future Scenarios*

Introduction

In addition to its environmental benefits, the use of renewable energy sources (RES) may contribute to increasing energy security. Among others, this fact is attributed to the indigenous availability of RES. At the same time, however, an increased use of RES involves certain risks to energy security. To give an example, an increased use of wind energy and its fluctuating electricity output could pose problems for system management and the existing electricity grid. Due to the heterogeneity of RES, with regard to their availability, energy conversion costs or other techno-economic characteristics, a detailed knowledge about these facts and the existing framework conditions is required for the evaluation of the role of RES for energy security. This background paper first introduces a general overview of RES characteristics in the context of energy security. Specific characteristics of different existing RES and the corresponding conversion technologies are described with a focus on the technological and the economic dimensions. In addition, special attention is drawn to the dynamics of RES' economic characteristics. Based on this information, insights into the main opportunities and risks of RES for energy security are provided.

Taking into account the benefits of RES in terms of environmental factors and increase in security of supply, the EC pursues the objective to supply 20 percent of the gross final energy consumption in 2020 from RES (The European Parliament and the Council of the European Union 2009). Nevertheless, the use of RES usually involves higher generation costs compared to the use of most conventional energy conversion technologies. To compensate for the economic disadvantages of some RES technologies, national governments have implemented different policy schemes that provide financial support for such technologies in order to make projects economically feasible. The major policy schemes in the electricity sector represent feed-in tariffs and quota obligations with an integrated trade of green certificates. In the first case, a fixed tariff is paid for one unit of renewable electricity or a premium is paid for one unit of renewable electricity on top of the market price. The quantity of renewable electricity is then a result of the predetermined tariff level. In contrast, in the case of quota obligations, the government sets targets for renewable electricity generation; and the price of the green certificate is a consequence of the predetermined target. With respect to the heat sector, the most applied support schemes are investment and fuel incentives. Regarding the transport sector, the European Commission in a Directive in 2003 proposed a certain annual quota of biofuel use.

Against this background, this chapter estimates the potential quantitative contribution of RES to increase security of supply according to different scenarios. Based on the existing simulation model Green-X and its detailed RES database, three future scenarios are presented referring to the overall SECURE policy storylines. Subsequently, results of the scenario calculations are presented, involving the analysis of the costs arising from an increased use of RES, which is again caused by the application of renewables support schemes in the respective scenario. In addition, some policy options of how to promote renewable energy sources effectively and efficiently are evaluated.

*This paper was written by Christian Panzer (EEG TU-WIEN) and Anne Held (Frauenhofer Institut)

1. Characteristics of Renewable Energy Conversion Technologies

A broad set of different energy conversion technologies options using RES exist today. However, these technologies differ considerably with regard to the stage of technological and market development as some are at an advanced stage of development while others are still at the initial stage.

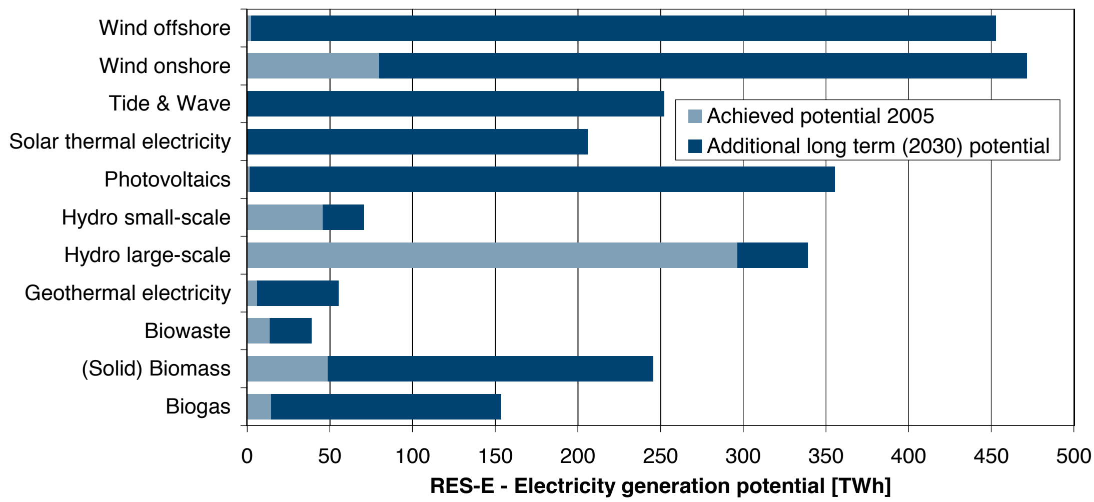
Additionally, the economic dimension of RES technologies influences their market development. The second section discusses the present range of energy conversion costs of RES technologies, consisting mainly in capital costs of RES within all three energy sectors, as well as possible future cost developments.

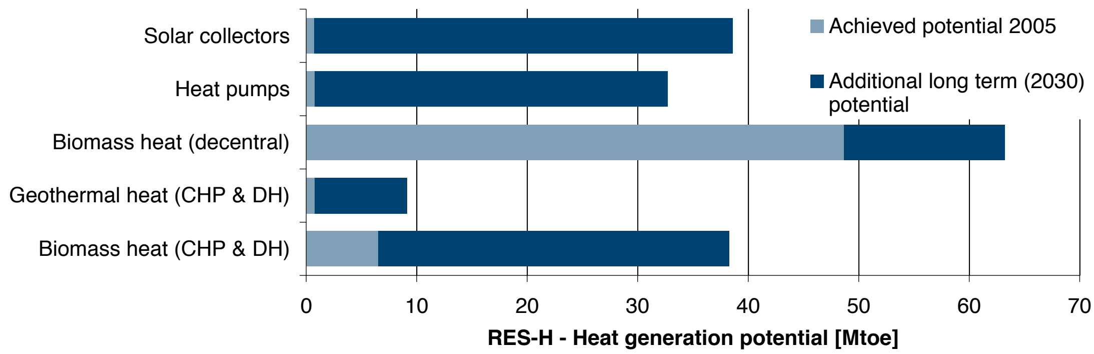
Due to the domestic nature of most RES conversion technologies, they contribute significantly to increasing Europe's import independence from fossil fuels. On the other hand, RES may involve higher risks due to the usage of novel technologies, output volatility and political circumstances.

1.1 The Technological Dimension of Renewable Energy Conversion Technologies

From a theoretical viewpoint, a broad range of RES is eligible for various conversion technologies. But due to existing constraints regarding the available resource potential, in the final count, the number of RES that are convertible is limited. The following part addresses the different RES potential categories. It also gives some figures of currently installed and identified RES potentials that are realizable up to the year 2030.

- Theoretical potential: For deriving the theoretical potential general physical parameters have to be taken into account (e.g. based on the determination of the energy flow resulting from a certain energy resource within the investigated region). It represents the upper limit of what can be produced from a certain energy resource from a theoretical point-of-view – of course, based on current scientific knowledge;
- Technical potential: If technical boundary conditions (i.e. efficiencies of conversion





technologies, overall technical limitations as e.g. the available land area to install wind turbines as well as the availability of raw materials) are considered the technical potential can be derived. For most resources the technical potential must be considered in a dynamic context – e.g. with increased R&D, conversion technologies might be improved and, hence, the technical potential would increase;

- Realizable potential: The realizable potential represents the achievable potential assuming that all existing barriers can be overcome and all driving forces are active. The realizable potential is limited by assumed maximum market growth rates and planning constraints. Therefore, the realizable potential has to refer to a certain year – it becomes substantially higher the further one looks into the future.

1.2 The Economic Dimension of Renewable Energy Technologies

The economic dimension is an important aspect that will determine the future growth rates of RES technologies. On the one hand, up-front investment costs are of relevance for potential investors, since these will determine the resulting generation costs and the achievable profit. On the other hand, future cost reductions will change the overall specific investment expenditures.

1.2.1 Current Economic Characteristics of Renewable Energy Conversion Technologies

The broad range of costs for several RES technology options is caused by site specific conditions, for example, Photovoltaics or wind energy locations. Then, costs strongly depend on the available technological options – compare, for example, co-firing and small-scale CHP plants for biomass. Demand-specific conditions leading to various degrees of utilization (e.g. full load hours in case of heating systems) also affect economics of RES technologies. All factors together lead to a broad range of conversion costs.

Nevertheless, in order to give a better illustration of the current economic conditions of the various RES options in the electricity sector some examples are pointed out here. According to the above mentioned impact parameters, wind onshore generation costs vary between 60 €2006/MWh and 105 €2006/MWh whereas offshore wind generation cost reach up to 150 €2006/MWh. The biggest range of generation costs is noted in the Biomass sector from 50 €2006/MWh to 210 €2006/MWh. At the end of the scale solar energy converters, especially Photovoltaics amount to 380 €2006/MWh up to 1200 €/MWh.

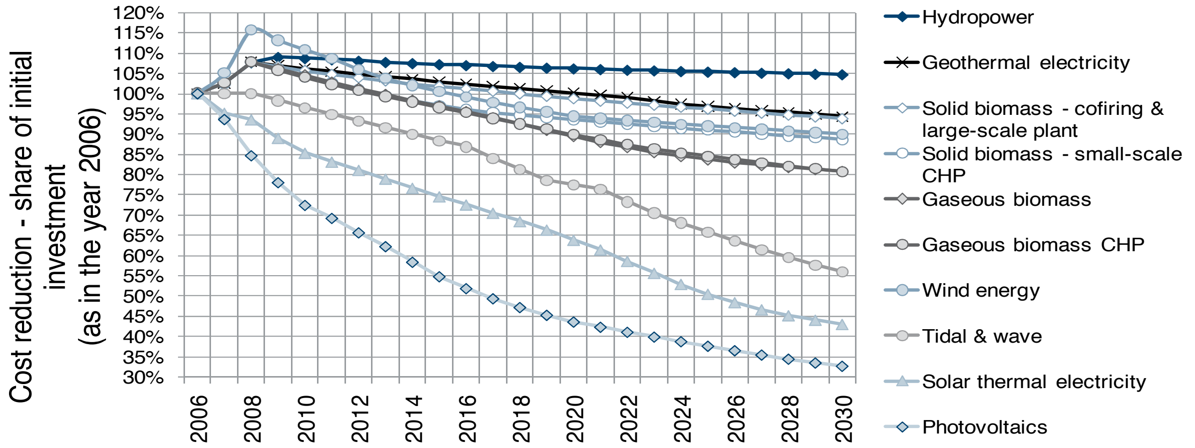
In contrast, the heat sector distinguishes between grid connected heat supply and non-grid connected heat supply, wherein the latter faces higher market prices. Among the RES-H technologies, solid biomass is in most cases within the non-grid connected sector, already competitive with conventional options (50 €2006/MWh to 75 €2006/MWh). Again solar thermal power generation is on the upper end at 75€ 2006/MWh up to 200 €2006/MWh. Grid connected heat supply systems vary between 30 €2006/MWh and 120 €2006/MWh.

Finally, in the transport sector the costs of all technologies are still above the current market price and therefore depend on financial support measures (bioethanol 60 €2006/MWh to 100 €2006/MWh and biodiesel 55 €2006/MWh to 65 €2006/MWh).

1.2.2 Future Development of Economics of Renewable Energy Conversion Technologies

With respect to the future cost development, technological learning is a crucial parameter, especially in the mid- to long term. Technological learning considers a certain cost reduction with each doubling of produced output. As learning takes place on the international level, the deployment of a technology on the global level must be considered. In order to illustrate the development of initial investment costs, influenced by learning effects but also by other parameters such as raw material prices and oil prices, Figure 1 depicts the cost development exemplarily for the electricity generation technologies up to the year 2030. Remarkable is the negative development in the period 2007 to 2009 for most energy

Figure 1 Cost Reduction of RES-E Investments as Share of Initial Investment Costs (2006) in a Pessimistic Scenario with regard to Technological Progress according to the "Policy Case"



Source: Green-X calculations

technologies, but obviously mostly affecting the cost of wind energy converters, is remarkable. This increase in investment cost is largely driven by the tremendous rise of energy and raw material prices as observed in recent years and was expected to prolong in the near to mid future. In this context, the impact of rising energy and raw material prices even compensates the cost reductions achieved due to technological learning. So, although technology learning is achieved, the overall investment costs are increasing in this period. However, still substantial cost reductions are expected for novel technology options such as photovoltaics, solar thermal electricity or tidal stream and wave power.

1.3 Opportunity of Renewable Energy Sources to Security of Supply

As stated by Ölz et al. 2007,[1] the use of RES may contribute to increasing energy security due to several characteristics.

First, since RES mainly represent indigenous resources, the replacement of imported fossil primary energy carriers, such as gas or coal, leads to a reduction of import dependency.

Second, the decentralized availability of RES and predominantly small plant sizes often leads to decentralized generation resulting in the following advantages: firstly, less infrastructural risks as the plants may be located closer to the demand involving a reduced risk for the grid infrastructure; secondly, the impacts of potential shutdowns or blackouts on the electricity system are reduced.

Third, RES technologies with the exception of biomass-based applications are not dependent on any fuel costs. Hence, in contrast to conventional energy conversion technologies based on the use of fossil fuels, there are neither fuel price fluctuations nor risks. Furthermore, the use of RES technologies in the electricity market under certain support conditions may have an impact on electricity prices. In this way, Sensfuß et al. 2008 calculate the impact of wind power feed-in on electricity prices using the example of Germany.[2] Following the basic mechanism of electricity markets, where the operation of electricity generation plants is selected according to the merit order of the marginal costs, wind electricity may replace generation options with high marginal costs, as for example, gas turbines, in periods of peak load. Thus, electricity prices are affected by the wind power feed-in.

Finally, a diversification of the existing power plant portfolio through an increased use of RES may lead to the portfolio effect and therewith reduce risks. Figure 2 summarizes the opportunities identified for RES to contribute to security of supply.

Figure 2: Overview of Opportunities for Security of Supply regarding RES

Decentralised character	Mainly indigenous resources	No fuel cost (except BM)	Portfolio effect
• Location closed to demand → Less infrastructure risk • Reduced impact on electricity system in case of shutdowns	• Reduction of import dependency	• Reduction of price risks induced by fossil fuel prices • Price effect of wind power feed-in	• Diversification of power plant portfolio

1.4 The Risk of Renewable Energy Conversion Technologies to Security of Supply in the Electricity Sector

Assessing the risk of RES technologies to security of supply implies investigation of many parameters on the technology level. Generally, a RES conversion plant shows different risk with respect to security of supply, depending on the plant size. If, for instance, a large-scale hydro power plant suddenly ceases to produce electricity, the impact on security of supply is much higher than if one wind turbine does not generate its forecast electricity amount.

Furthermore, the risk of volatile fuel costs does not affect every RES technology to the same extent. Thus, some technologies in the electricity sector show a very volatile energy output in the short-term and others more in the long-term, while some others do not show any volatile energy output at all. Generally, it should be mentioned that the volatile energy output represents one of the most relevant risks of RES, since they require a certain amount of back-up capacity in the energy system and therefore do not contribute largely to the overall security of energy supply.

Economic risk parameters are very sensitive to the overall risk assessment of a renewable technology. On the one hand, the current economic crunch will decrease the overall energy demand and, therefore, contribute positively to energy supply security, while on the other hand the financial crises could hamper a strong growth of RES. In this context, an adequate and long-term stable policy framework is required in order to attract potential investors.

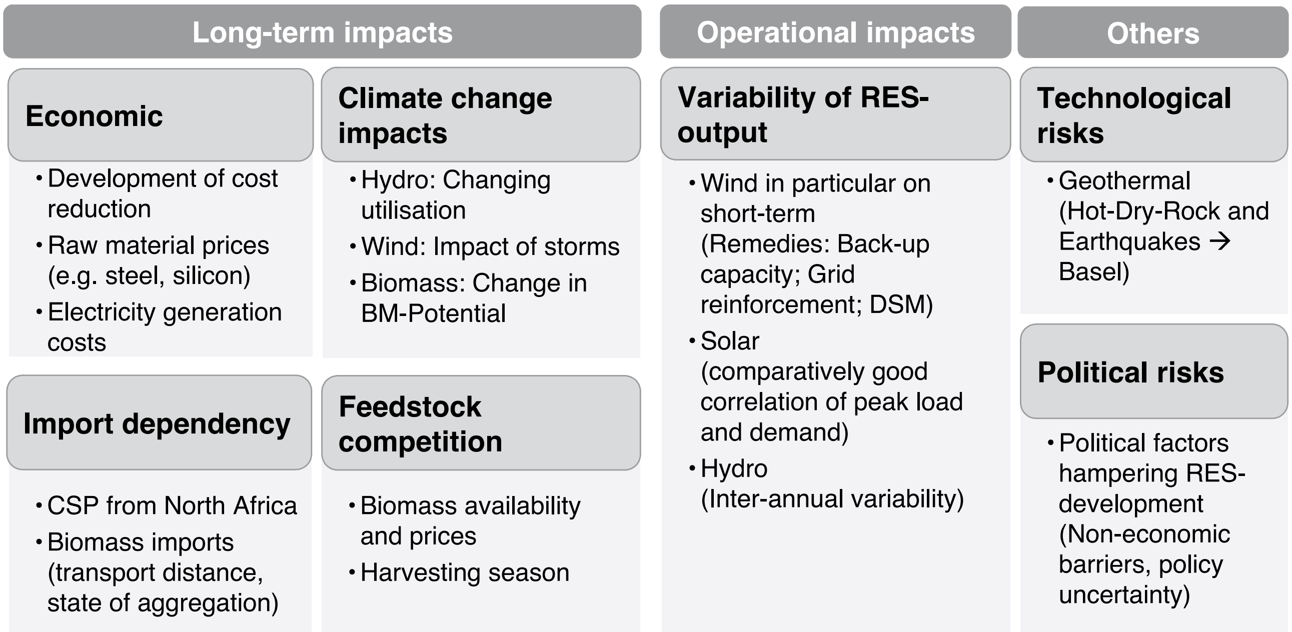
According to Figure 3 the assessment of risk can be made in terms of long-term impacts, operational impacts and others. Generally, the risk assessment depends on the type and penetration of RES and system characteristics:

- The higher the penetration of RES, the higher is the risk of volatile power outputs.
- The more diverse the portfolio of renewable technologies, the smaller is the impact of price volatilities.
- The more stable the political framework conditions, the lower is the risk for potential investors
- The higher the share of domestic energy production, the higher the security of supply – as a domestic energy resource, a large contribution of RES is required by exploiting all kinds of technologies in order to establish a reliable, constant renewable energy system.

2. Future Pathways of RES and Associated Policy Costs

Taking into account technical and economic constraints of RES technologies, discussed above, this section provides quantitative analysis of potential future RES pathways up to 2030, according to the three main policy lines within the SECURE project. Three different demand projections accompanied by the associated energy prices form the basis of the policy themes on the one hand; on the other hand, the differently implemented RES support measures are of high relevance for the results. Moreover, all scenarios refer to realizable RES potentials of renewable energies (see Panzer

Figure 3: Overview of Threat Identification for Security of Supply regarding RES



et al, 2009) determined for this chapter, taking into account dynamic aspects. The assessment of future renewable energy pathways in terms of development is based on scenario calculations seeking to meet the overall 20 percent RES by 2020 target in the EU.

The first sub-section focuses on the possible future development of renewable energies in all three energy sectors in terms of quantitative capacity installations as well as generation in the European Union. Additionally, potential surpluses and shortfalls with respect to the 20 percent RES by 2020 target are discussed here. These analyses depict the impact of national policy schemes on future development in all three policy themes. Consequently, the second sub-section provides a comparison of additional generation costs due to enhanced RES development and highlights the difference in society costs.

2.1 Pathways of RES Deployment

2.1.1 Muddling Through – Business as Usual:

This scenario is characterized by high gross final energy demand growth rates in all sectors on global scale accompanied by relatively low raw energy prices. However, the projected sectoral contribution can be analyzed best by depicting deployment on sectoral level in relative terms – i.e. by indicating the deployment of RES-E, RES-H and RES-T as shares of corresponding gross demands. In this context, Table 1 gives an overview on results for 2006 – forming the starting year of the simulation – 2010, 2020 and 2030. Although a constant increase of the share of renewables can be observed in all sectors, the overall development of renewables fails to meet the 20 percent RES by 2020 target by far. In this respect, renewables only contribute to 13 percent to the overall gross final energy demand in 2020. Nevertheless, the strongest increase is seen in the electricity sector where almost a quarter of the electricity demand is met by renewables. The share of biofuels in transport fuel demand remains comparatively low throughout the decades up to 2030. Generally, the relatively slow increase of renewables even slows down beyond 2020 and results at 15 percent RES on gross final energy demand in 2030.

Next, the RES development is discussed on technology level for each energy sector. The bulk of RES-E in 2030, illustrated in Figure 4, will be mostly produced by technologies that are already at present well established or close to the market. Hence, wind onshore (378 TWh/yr), large-scale hydro (320 TWh/yr), solid biomass (128 TWh/yr), biogas (78 TWh/yr), small hydro (55 TWh/yr) will contribute about 83.7 percent to RES-E production. In contrast, novel RES-E options with huge future potentials such as PV (60 TWh/yr), solar thermal electricity (113 TWh/yr) or tidal & wave energy (35 TWh/yr) and wind offshore (33 TWh/yr) enter the market and achieve a steadily growing share. However, remarkable contributions can, under a Business as Usual scenario, only be expected in the period beyond 2020. Generally, current support measures lead to an increased share of RES-E generation, but mainly driven by already experienced technologies, whereas the development of novel technologies is strongly limited, also caused by existing non-economic barriers.

In contrast to the electricity sector, the renewable heat sector is under Business as Usual circumstances also strongly dominated by already well established energy technologies, where, as already mentioned, the biggest RES share is achieved in the individual, non-grid heat sector. Here solid biomass generated about 50 Mtoe in 2006 but only grows to 54 Mtoe in 2030, whereas novel technologies like heat pumps (2.3 Mtoe) and solar thermal heat and water (3.4 Mtoe) show bigger growth rates. Nevertheless, biomass plays a crucial role in the heat sector and, besides in the individual heating plants, is also often used in co-firing plants. With respect to the overall target achievement of 20 percent RES by 2020, which has failed under Business as Usual, it must be concluded that strong efforts have to be made in the heat sector to achieve a much higher growth rate than the 8.5 percent increase seen in Figure 5.

Finally, the development of the renewable transport sector according to the Business as Usual scenario is given in Figure 6. Traditional biofuel generation triples beyond 2010 from 3 Mtoe as of 2006 to 9 Mtoe by 2030. Additional contribution is expected from advanced biofuel generation (second

Table 1: Share of Renewable Energies in Electricity, Heat and Transport Fuel Demand

% deployment	European Union 27				
	2006	2010	2020	2030	
Share of RES-E on electricity demand	16%	20%	35%	50%	
Share of RES-H on heat demand	10%	12%	20%	31%	
Share of RES-T on transport fuel demand	1%	2%	8%	10%	
Share of RES on final demand	**9%**	**11%**	**20%**	**30%**	
Share of RES on primary demand	7%	9%	18%	26%	*(Eurostat convention)*
	10%	13%	23%	35%	*(Substitution principle)*

Figure 4: Future Renewable Energy Generation within the Electricity Sector in the European Union up to 2030 on Technology Level according to the Muddling Through Scenario

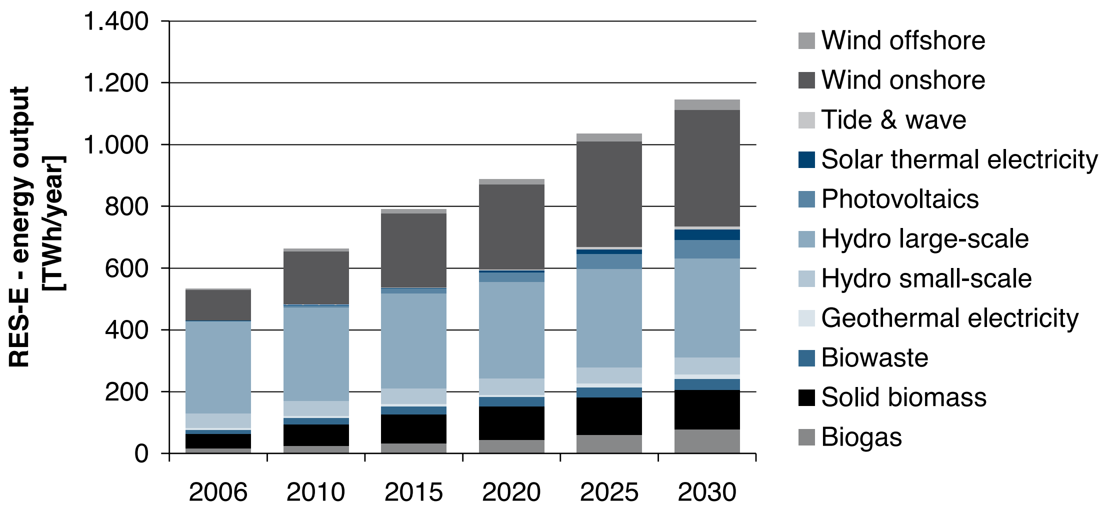
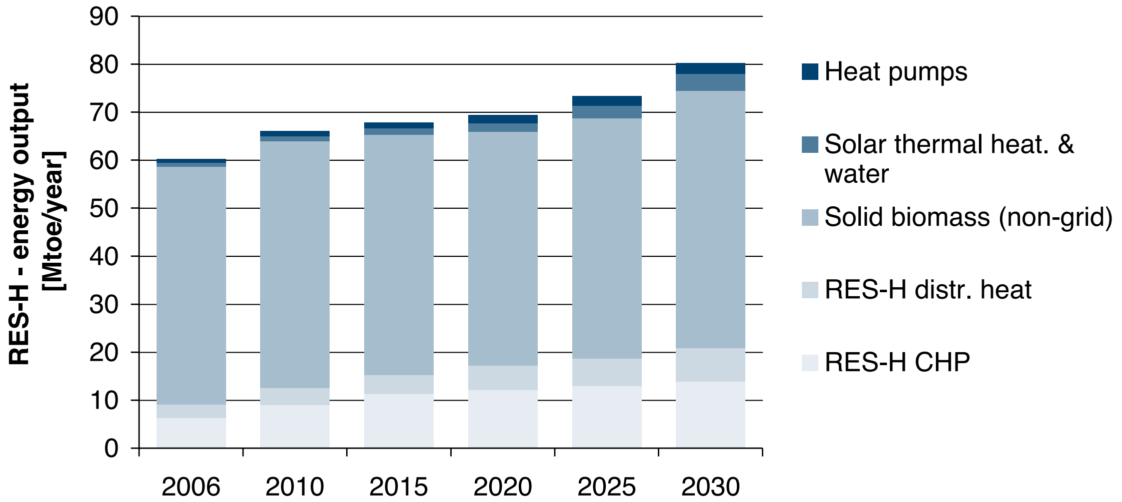


Figure 5: Future Renewable Energy Generation within the Heat Sector in the European Union up to 2030 on Technology Level according to the Muddling Through Scenario



generation – Fischer Tropsch, etc.) beyond 2015 up to 3 Mtoe in 2030. However, substantial increases are still considered in the biofuel import from abroad which amounts to 14 Mtoe in 2030. Generally, as shown in Table 1 the Business as Usual scenario does not meet either the 20 percent RES by 2020 target or the 10 percent biofuel by 2020 target.

In conclusion of this scenario, under Business as Usual conditions the largest renewable energy contribution is achieved in the electricity sector throughout Europe whereas the heat sector almost levels off up to 2030 due to missing support incentives.

2.1.2 Europe Alone – Strengthened National Policy:

In contrast to the scenario above, the Europe Alone scenario is characterized by strong emphasis on climate change issues at the European level implying low energy demand forecasts for the EU accompanied by relatively high raw energy and CO_2 prices but hardly any restrictions for the rest of the

Figure 6: Future Renewable Energy Generation within the Transport Sector in the European Union up to 2030 on Technology Level according to the Muddling Through Scenario

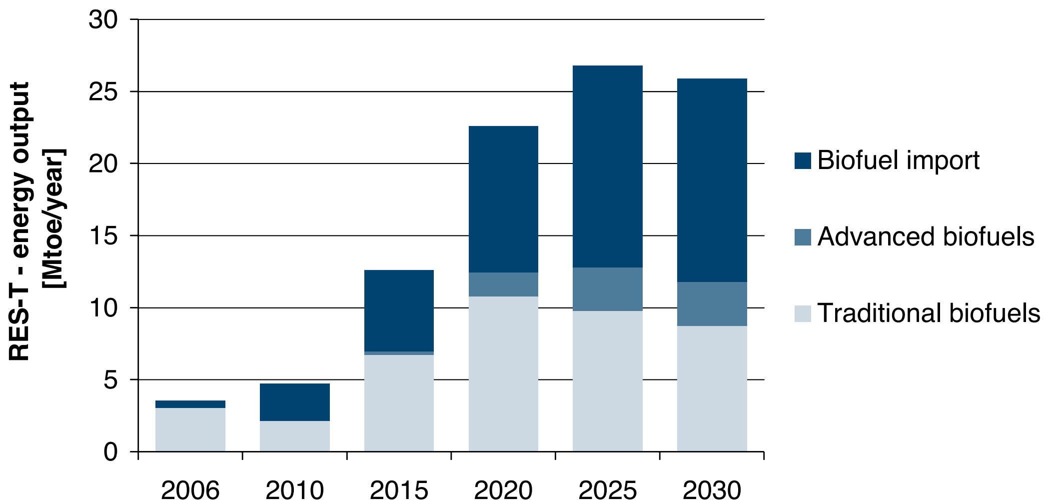


Table 2: Share of Renewable Energies in Electricity, Heat and Transport Fuel Demand

% deployment	European Union 27				
	2006	2010	2020	2030	
Share of RES-E on electricity demand	16%	20%	35%	50%	
Share of RES-H on heat demand	10%	12%	20%	31%	
Share of RES-T on transport fuel demand	1%	2%	8%	10%	
Share of RES on final demand	**9%**	**11%**	**20%**	**30%**	
Share of RES on primary demand	7%	9%	18%	26%	*(Eurostat convention)*
	10%	13%	23%	35%	*(Substitution principle)*

world. Hence, renewable energy support measures are strengthened with respect to effectiveness and efficiency. The projected sectoral contribution in relative terms – i.e. by indicating the deployment of RES-E, RES-H and RES-T as shares of corresponding gross demands is depicted in Table 2. A strong increase of the share of renewables can be observed throughout all sectors, where the electricity sector even takes off stronger beyond 2020. In total, the overall development of renewables meets the 20 percent RES by 2020 target exactly; additionally, the biofuel target of 10 percent RES on diesel and gasoline in 2020 will be met. The biggest share of RES is still projected for the electricity sector where about half of the electricity demand is met by renewables in 2030. Generally, the strong increase of about one percent each year of renewables between 2010 and 2020 even continues beyond 2020 and results at 30 percent RES on gross final energy demand in 2030.

The RES development is separately discussed on the technology level for each energy sector. Caused by the high renewable energy share of about 50 percent in the electricity sector, the total amount of RES-E in 2030, illustrated in Figure 7, cannot solely be produced by technologies that are already well established or close to the market. However, wind onshore (477 TWh/yr), large-scale hydro (325 TWh/yr), solid biomass (228 TWh/yr), biogas (134 TWh/yr), small hydro (65 TWh/yr) will still contribute about 61.3 percent to RES-E production. Wind onshore already holds a higher share of RES-E than the currently dominant large-scale hydro power. In contrast, other RES-E options with huge future potentials such as PV (173 TWh/yr), solar thermal electricity (125 TWh/yr) or tidal & wave energy (72 TWh/yr), and especially wind offshore (360 TWh/yr), enter the market and achieve a strong and steadily growing share. Generally, improved support measures lead to a strong increase of the RES-E share with a broad portfolio of different technologies which is also a result of the overcoming of existing non-economic barriers.

Figure 7: Future Renewable Energy Generation within the Electricity Sector in the European Union up to 2030 on Technology Level according to the Europe Alone Scenario

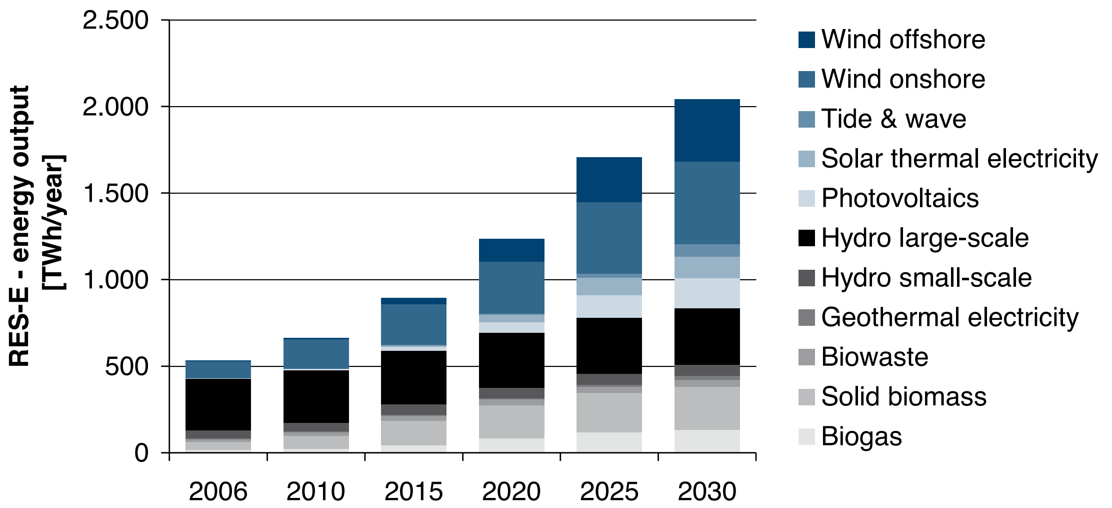
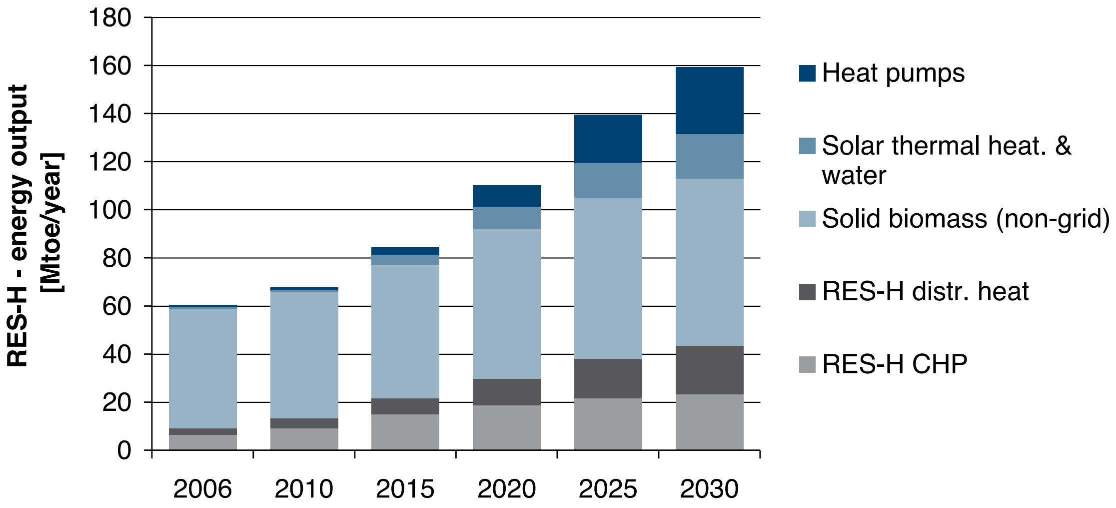
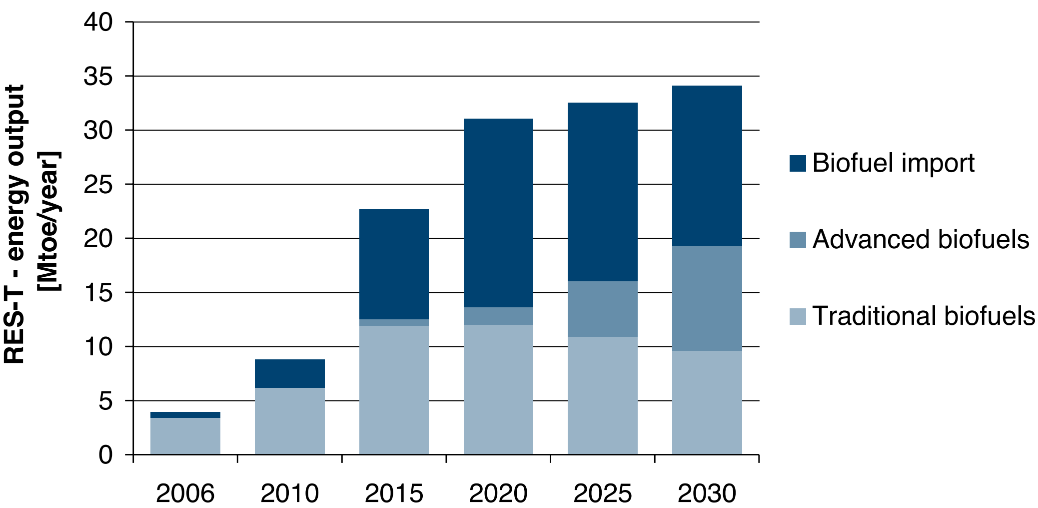


Figure 8: Future Renewable Energy Generation within the Heat Sector in the European Union up to 2030 on Technology Level according to the Europe Alone Scenario



Like the electricity sector, the renewable heat sector provides a big portfolio of different technologies in case of strengthened national policy measures. However, the biggest share is still achieved in the individual, non-grid heat sector which is supplied by solid biomass, solar thermal heat and water as well as heat pumps. Nevertheless, as already mentioned, about 27 percent is supplied by more efficient Combined Heat and Power plants. Solid biomass generated about 50 Mtoe in 2006 and grows to 69 Mtoe in 2030, whereas novel technologies, holding hardly any share in 2006, like heat pumps (28 Mtoe) and solar thermal heat & water (19 Mtoe) show much bigger growth rates. Nevertheless, biomass plays a crucial role in the heat sector and besides in the individual heating plants also often used in cofiring plants. With respect to the overall target achievement of 20 percent RES by 2020, which is met under strengthened national policies, it must be concluded that strong efforts have to be put on the heat sector in order to achieve a much this doubling of renewables in the heat sector compared to the Business as Usual

Figure 9: Future Renewable Energy Generation within the Transport Sector in the European Union up to 2030 on Technology Level according to the Europe Alone Scenario



case. Figure 8 shows the development of RES-H on technology level.

Figure 9, shows the development of the renewable transport sector according to the strengthened national policy scenario. Traditional biofuel generation triples beyond 2010 from 3 Mtoe as of 2006 to 9 Mtoe by 2030. Additional contribution is expected from advanced biofuel generation (second generation – Fischer Tropsch, etc.) beyond 2015 going up to 10 Mtoe in 2030. Generally, traditional biofuel generation equals the amount under the Business as Usual scenario whereas still high exploitable potentials are considered in the advanced biofuel technologies. However, substantial increases are still considered in the biofuel import from abroad which amounts to 15 Mtoe in 2030. Consequently, as shown in Table 2, the strengthened national policy scenario does meet both the 20 percent RES by 2020 target and the 10 percent biofuel by 2020 target; the latter refers to 10 percent biofuel on solely diesel and gasoline demand.

Given the uneven distribution of RES potentials within the European Union, member states are entitled to install flexibility mechanisms in order to exploit their RES potentials in a least-cost approach. Generally, also in this scenario, the electricity sector is still the strongest contributor of renewable energy, but the heat sector takes up strongly.

2.1.3 Global Regime (Full Trade) – Strengthened National Policy:

Principally, the Global Regime (Full Trade) scenario implies a strong emphasis on climate change issues on not only the European level but on global scale. Hence, energy demand growth forecasts are relatively low, but for Europe higher than the Europe Alone scenario, since it is not expected that the industry will strongly shift abroad. Caused by the low energy demand on global scale, raw energy prices are low and CO2 prices are not as high as in the Europe Alone scenario, due to the global trade opportunity. However, renewable energy support measures are strengthened with respect to effectiveness and efficiency in order to pursue the 20 percent RES by 2020 target. The projected sectoral contribution in relative terms – i.e. by indicating the deployment of RES-E, RES-H and RES-T as shares of corresponding gross demands is depicted in Table 3. Generally, a strong increase of the share of renewables can be observed throughout all sectors, although the electricity sector slightly slows down close to 2030 and more development is then projected in the heat sector driven by a stronger demand increase in the electricity sector beyond 2020. In total, the overall development of renewables meets the 20 percent RES by 2020 target exactly; additionally the biofuel target of 10 percent RES on diesel and gasoline in 2020 will be met. The biggest share of RES is still projected for the electricity sector where slightly less than half of the electricity demand is met by renewables in 2030. Generally, the strong increase of about one percent each year of renewables between 2010 and 2020 even continues beyond 2020 and results at 29 percent RES on gross final energy demand in 2030.

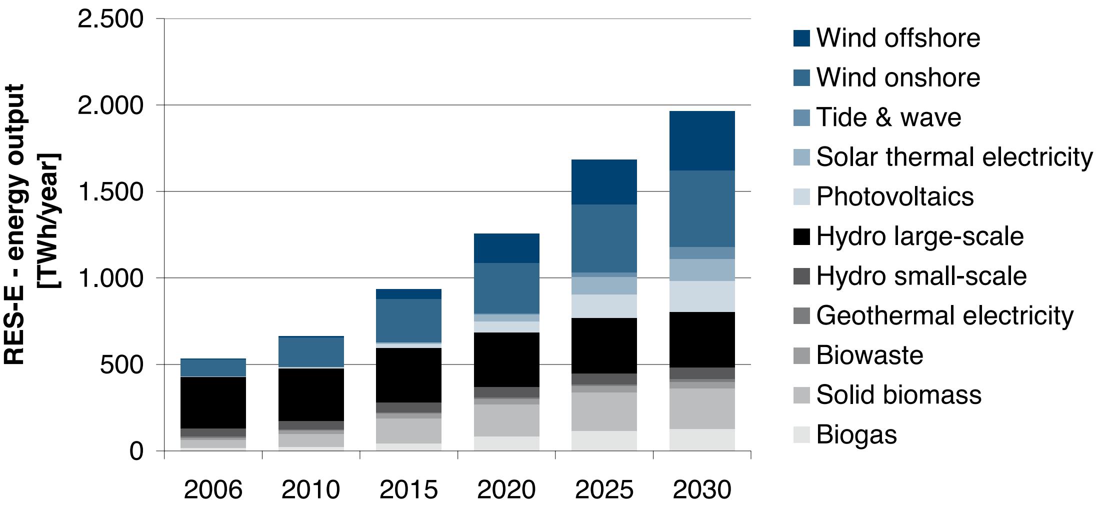
In the following, RES development is discussed in depth on technology level for each energy sector. In order to achieve the high renewables share of about 48 percent in the electricity sector, the total amount of RES-E in 2030, illustrated in Figure 10, a broad portfolio of different energy conversion technologies is required. However, wind onshore (442 TWh/yr), large-scale hydro (323 TWh/yr), solid biomass (233 TWh/yr), biogas (129 TWh/yr), small hydro (65 TWh/yr) will still contribute to about 60.6 percent to RES-E production. Wind onshore already

Table 3: Share of Renewable Energies in Electricity, Heat and Transport Fuel Demand

% deployment	European Union 27				
	2006	2010	2020	2030	
Share of RES-E on electricity demand	16%	20%	36%	48%	
Share of RES-H on heat demand	10%	12%	19%	30%	
Share of RES-T on transport fuel demand	1%	2%	8%	10%	
Share of RES on final demand	**9%**	**11%**	**20%**	**29%**	
Share of RES on primary demand	7%	9%	18%	25%	*(Eurostat convention)*
	10%	13%	23%	33%	*(Substitution principle)*

holds a higher share of RES-E than the currently dominant large-scale hydro power. Additionally, wind offshore shows the strongest overall increase and amounts to 343 TWh/yr in 2030 so that wind energy in total already provides 40 percent of the overall RES-E generation. In contrast, novel RES-E options with huge future potentials such as PV (180 TWh/yr), solar thermal electricity (126 TWh/yr) or tidal and wave energy (71 TWh/yr) enter the market and achieve a strong and steadily growing share. It is necessary to emphasize that this broad portfolio of different technologies, required in order to meet the 20 percent target in 2020, is only achieved when the existing non-economic barriers are overcome.

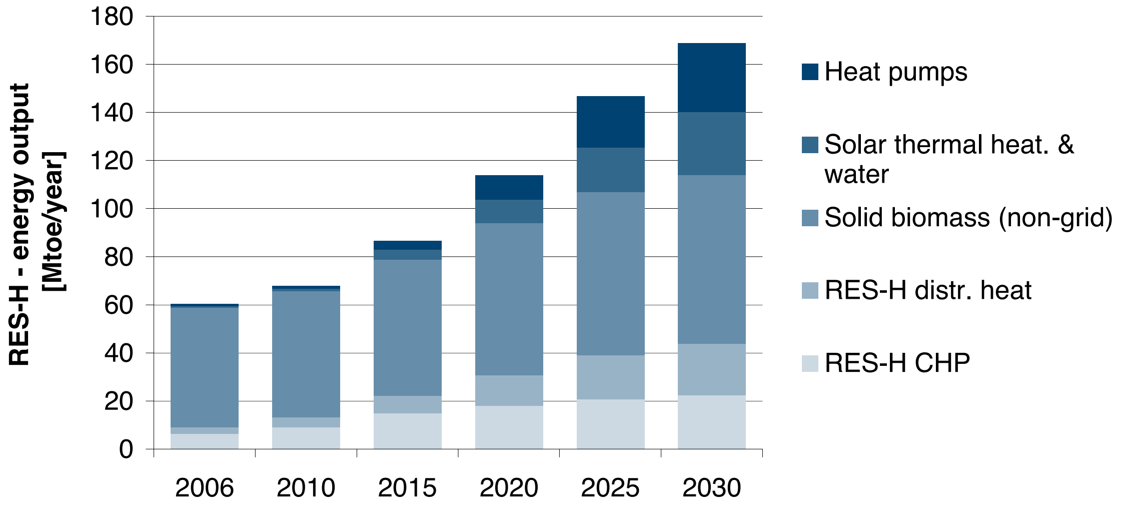
Figure 10: Future Renewable Energy Generation within the Electricity Sector in the European Union up to 2030 on Technology Level according to the Global Regime Scenario



As discussed in the electricity sector, the renewable heat sector also holds a big portfolio of different technologies in case of strengthened national policy measures. Although the biggest share of RES-H is still achieved in the individual, non-grid sector which is supplied by solid biomass, solar thermal heat and water as well as heat pumps about one quarter of the overall renewable heat is generated centrally and connected to distribution networks. In contrast, within the non-grid connected heat supply solid biomass generated about 50 Mtoe in 2006 and grows to 70 Mtoe in 2030, whereas novel technologies, holding hardly any share in 2006, like heat pumps (29 Mtoe) and solar thermal heat and water (26 Mtoe) show much bigger growth rates. Hence, the scenario predicts a decrease of the share of solid biomass within the non-grid heat sector from almost 100 percent now to below 45 percent up to 2030. Nevertheless, biomass plays a crucial role in the heat sector and, besides the individual heating plants, is also often used in co-firing plants. With respect to the overall target achievement of 20 percent RES by 2020, which is met under strengthened national policies, it must be concluded that strong efforts have to be put on the heat sector in order to achieve a doubling of renewables in the heat sector compared to the Business as Usual case. Figure 11 shows the development of RES-H on technology level.

Figure 12 illustrates, according to the strengthened national policy scenario, the development of the renewables in the transport sector. Generally, the global CO_2 constraints scenario results in a slightly higher transport fuel demand. Hence, the overall RES-T generation contributes to 37.4 Mtoe, but the allocation of the three major contributors equals the Europe Alone scenario. Traditional biofuel generation triples beyond 2010 from 3.4 Mtoe as of 2006 to 11.2 Mtoe by 2030. Additional contribution is expected from advanced biofuel generation (second generation – Fischer Tropsch, etc.) beyond 2020 up to 10 Mtoe in 2030. Generally, traditional biofuel

Figure 11: Future RES Generation within the Heat Sector in the EU on Technology Level according to the Global Regime Scenario



generation equals the amount under the Business as Usual scenario whereas still high exploitable potentials are considered in the advanced biofuel technologies. However, substantial increases are still considered in the biofuel import from abroad which amounts to 17 Mtoe in 2030. Consequently, as shown in Table 3, the strengthened national policy scenario does meet both, the 20 percent RES by 2020 target and the 10 percent biofuel by 2020 target whereas the latter refers to 10 percent biofuel on solely diesel and gasoline demand.

2.2 Costs of Enhanced Renewable Energy Generation

Based on the future projections of renewable energies presented above, this section discusses the associated costs of the development in detail. The assessment of future renewable energy pathways and corresponding costs is based on the same scenario calculations seeking to meet the overall 20 percent RES by 2020 target in the EU. Consumer expenditures caused by the different policy

Figure 12: Future Renewable Energy Generation within the Transport Sector in the European Union up to 2030 on Technology Level

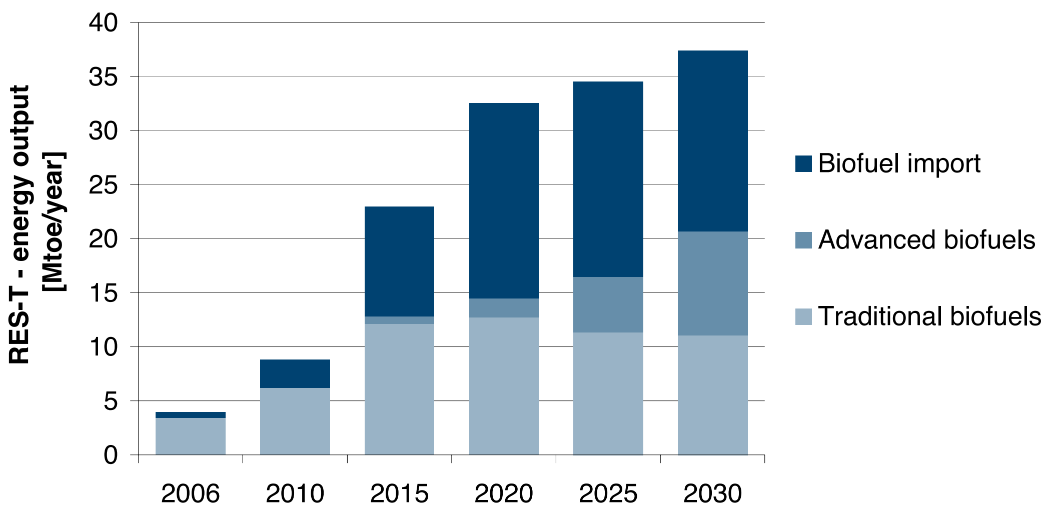
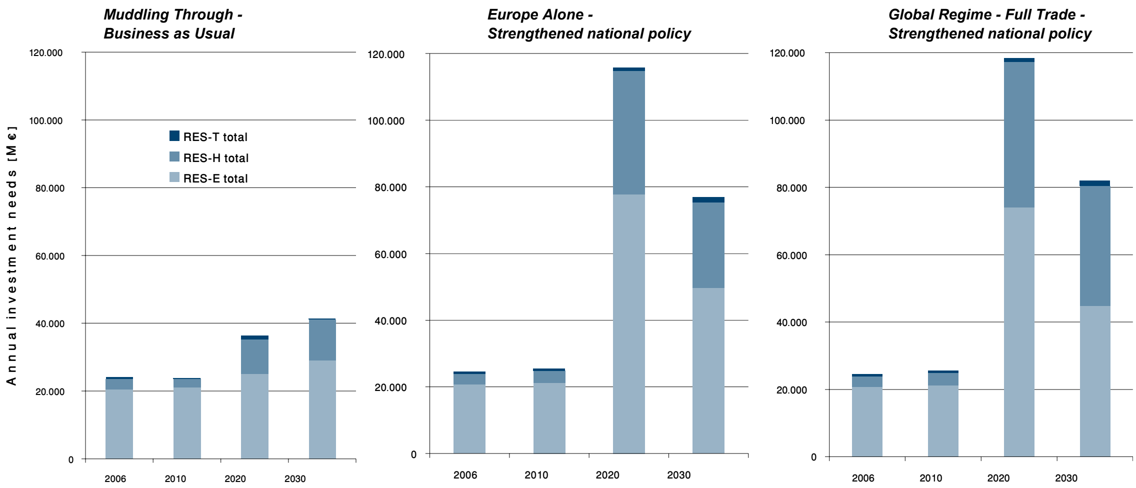


Figure 13: Annual Required Capital Expenditures in order to Achieve the Corresponding RES Generation for the Year 2006, 2010, 2020 and 2030 in Million Euro



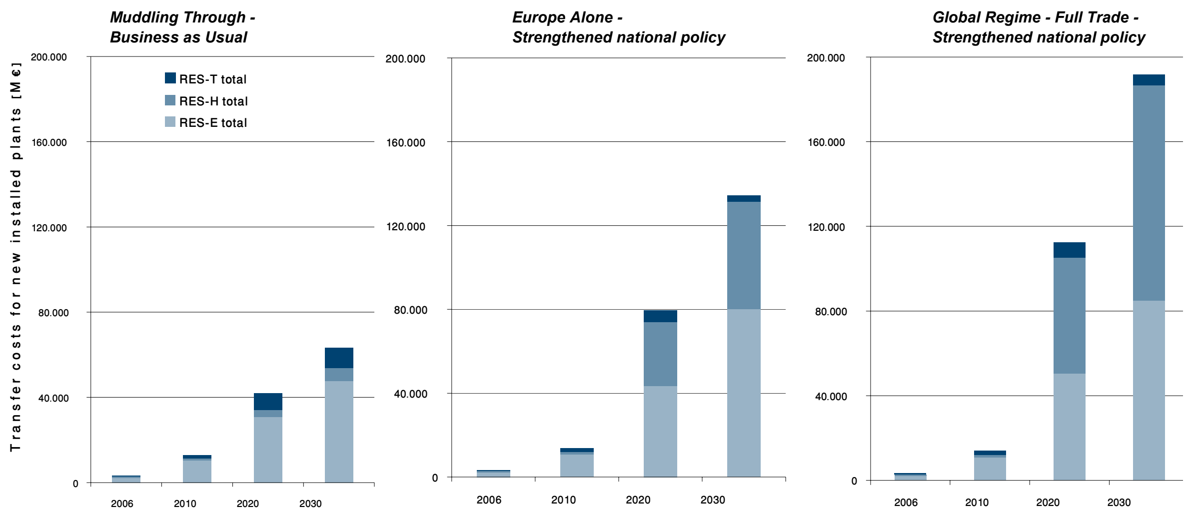
themes on future energy pathways are depicted In more detail and discussed along with additional generation costs of the corresponding RES development.

This paper focuses on the costs of the future development of renewable energies in all three energy sectors in line with the scenarios presented in the section above. Additionally, comparison of the deployment of renewable energies with the corresponding costs for the society will highlight the need for necessary design criteria for policy options.

2.2.1 Pathways of RES Deployment with Respect to its Costs

First, the capital expenditures needed in all three sectors are analyzed with respect to the three different policy themes, the Mudding Through, the Europe Alone and the Global Regime presented above. In order to achieve an ambitious share of renewables by 2020, huge investments have to be undertaken. Thus, it is necessary to implement efficient and effective policy measures in order to

Figure 14: Cumulated Transfer Costs to the Society due to RES Policy Measures according to Three Policy Themes in Million Euro on Sectoral Level



keep the RES surcharges for the energy consumers at a low level. Consequently, this section discusses the resulting costs for the society caused by the support of RES for all three policy themes.

Figure 13 demonstrates the annual needed capital expenditures within the Muddling Through - Business as Usual, Europe Alone - Strengthened National Policy and Global Regime (Full Trade) - Strengthened National Policy. Meeting the 20 percent RES by 2020, which only the two strengthened national policy schemes do, requires investments of about three times the investment needed in 2020 under current support options. Furthermore, comparing the three scenarios, it appears necessary that strong efforts have to be taken in the heat sector, where under BAU conditions only minor action is expected; meeting the 2020 target requires much higher contribution from the heat sector as well. Again, the capital expenditures reflect the higher energy demand in the Global Regime (Full Trade) scenario, resulting in more needed capital expenditures. When it comes to the period 2020 to 2030, partly due to the huge cost reductions of certain technologies less investment is needed in order to achieve approximately the same growth rate of 1 percent RES annually. These costs reductions are mainly driven by the assumed technological learning effects as well as efficiency improvements especially of novel technologies such as wind offshore, photovoltaic or solar thermal energy.

Transfer costs paid by the society are discussed in the following part. Depending on the support mechanism of RES plants, the investors receive a fixed or varying extra charge per energy unit generated on top of the energy market prices. Thus, transfer costs are determined by the difference of the cumulated costs of guaranteed support of RES plants to the energy wholesale market prices. These costs are then usually shared among all energy consumers. Thus, the design of financial support measures is very important to find the most efficient balance between the higher cost to the consumer and contribution from RES.

With respect to the Muddling Through – Business as Usual case, the annual transfer costs paid by the society are shown in Figure 14 (left figure) on sectoral level. In the Business as Usual case, although the stimulation of the RES markets is almost equal among the electricity and heat sector, the transfer costs are mainly relevant in the electricity sector. Since most of the realized renewable heat installations are within the individual sector they are already market competitive without additional support. However, keeping in mind that this scenario fails to meet the target in 2020 by far, strong emphasis has to be put in the renewable heat sector in this respect. In contrast, the transport sector lags behind in terms of RES generation but, nevertheless, is strongly dependent on financial support. In total, the policy costs amount to 42 billion Euro in 2020 and 63 billion Euro in 2030. With respect to the decrease of transfer costs in the year 2026 , it has to be taken into account that most RES technologies under Business as Usual conditions are eligible for financial support for 15 to 20 years, hence new installations from 2006 to 2010 are then on the market and, therefore, the overall policy costs are reduced.

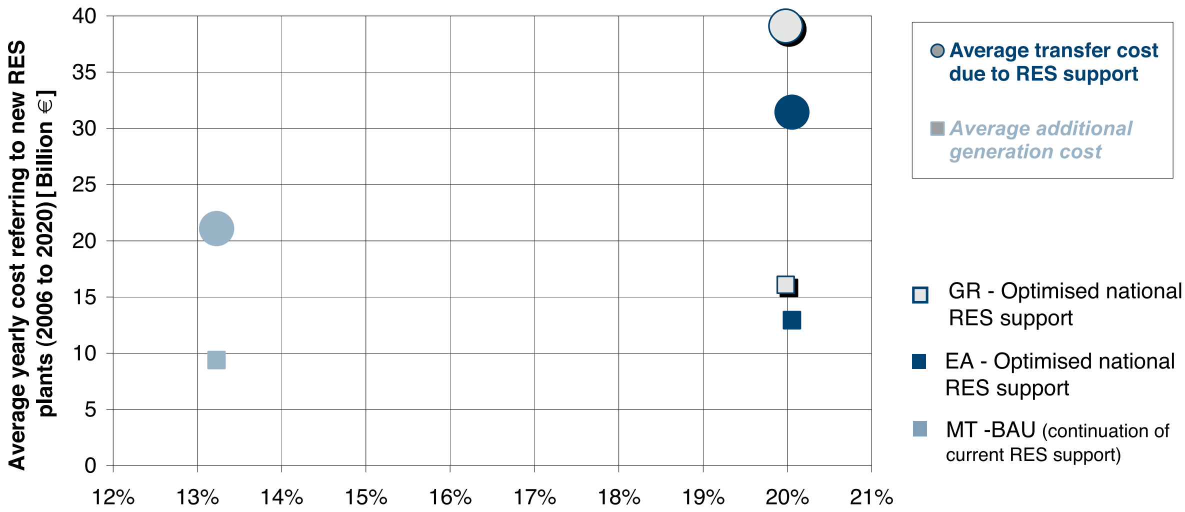
In contrast, in the Europe Alone – strengthened national policy case it is remarkable that on the one hand, obviously strong efforts are taken in the electricity sector, but on the other hand, transfer costs in the heat sector are expected to grow in the same magnitude. An ambitious RES deployment consequently asks for a strong contribution of all sectors. It is noticed that the transfer costs on sectoral as well as in total are increasing even more strongly beyond 2020. This fact is caused on the one hand by residual transfer costs from installations before 2020 as well as by the entry into the market of novel technologies, like solar and wind offshore energy. In total, the policy costs amount to 79.5 billion Euro in 2020 and 134 billion Euro in 2030. Special focus has to be put on the 2020 time horizon, when only less then a doubling of the overall transfer costs is sufficient to comply with the target but, as indicated above, covering three times more of the investment costs than in the Muddling Through case.

Finally, expected transfer costs within the Global Regime (Full Trade) based on strengthened national RES policies are depicted in Figure 14. As in the Europe Alone scenario, the Global Regime case also seeks to meet the 20 percent RES target.

Hence, obviously strong efforts are taken in the electricity sector and the heat sector. With respect to total RES development, the Global Regime (Full Trade) only results in slightly higher numbers than the Europe Alone case due to the higher gross final energy demand in the Global Regime (Full Trade). However, the resulting transfer costs are about 40 percent more in the Global Regime (Full Trade), since the preconditioned global CO2 constraints lead to overall lower raw energy prices, which consequently increase the need for policy support for RES. Again, notable is that the transfer costs, both sectoral as well as overall, will increase more strongly beyond 2020 due to residual transfer costs from installations before 2020 as well as when novel technologies, like solar and wind offshore energy, are entering into the market. In total, the policy costs amount to 112.5 billion Euro in 2020 and 191.7 billion Euro in 2030.

An in-depth analysis with respect to the achieved RES deployment and the corresponding costs according to the three policy themes is provided in Figure 15 on the 2020 time horizon. The Muddling Through scenario, representing a continuation of the currently implemented policy options, would lead to only 13.3 percent RES in 2020 at high transfer costs, covered by the energy consumer. Non-economic barriers hamper a stronger development of renewables in general; additionally hardly any support is available for the important sector of renewable heat. Furthermore, implemented policy options need to be strengthened with respect to their effectiveness, resulting in more RES installation due to improved usage of the transfer costs, and their efficiency, meaning the difference of real RES generation costs and their (guaranteed) support level, in order to comply with the target. These improvements are necessary for the Europe Alone and Global Regime scenarios. Both scenarios meet the target but at different costs, due to the different demand and energy price assumptions. Demand projections influence the average generation costs while the energy price influences the transfer costs.

Figure 15: Comparing Average Additional Generation Costs (Square) as well as Transfer Costs (Circle) for Consumer due to RES Support to the Achieved RES Share in 2020 for Different Demand Projections



Conclusion

The use of renewable energy sources (RES) for electricity, heat or transport fuel production involves positive implications for the mitigation of climate change and for security of energy supply. In particular the domestic character of most RES facilitates the reduction of import dependency on fossil fuels. As most technology options using RES are not yet competitive with established technology options, the European Union encourages member states to promote the use of RES economically. As a consequence of political support measures, the strongest dynamic development could be observed in the electricity sector, particularly with regard to the 'new' RES-technologies in Western European countries. A broad portfolio of technologies is being developed, though technologies such as hydropower, wind energy and solid biomass energy still dominate the overall composition.

Though there are positive impacts, an increased use of RES may constitute some risks for security of energy supply. In general, most RES-conversion technologies depend on the use of natural energy flows, resulting in a volatile character of the final energy output. These fluctuations may occur on varying time scales. Wind energy technologies or solar energy technologies show fluctuations on a short- to medium-term horizon, whereas hydro power output fluctuates rather on a seasonal level or even annually. The volatile character of some RES poses important challenges for the management of the electricity system and represents a risk for energy security. In addition, in both cases output volatilities are very sensitive to the electricity generation costs and may therefore have negative impacts on the economics of these plants.

In terms of the potential of RES in the time horizon of 2030, about 35 percent of the total gross final energy demand could be met by RES if all driving forces were active and all non-economic barriers were overcome. In a sectoral breakdown, this 35 percent is divided into 64 percent renewable electricity on gross final electricity demand, 30 percent renewable heat on gross final heat demand and about 11 percent of renewables in the transport sector. On the technology level, hydropower has historically dominated in the electricity sector and solid biomass in the heat sector, but in the long term several options such as wind, solar and geothermal energy will play an important role. Of course, these potentials are distributed very differently among the 27 EU member states necessitating a flexible exploitation of these RES potentials in order to meet the agreed EU targets.

Concerning the demand projections as well as raw energy prices, huge deviations appear regarding the three different, investigated policy themes (Muddling Through, Europe Alone and Global Regime [Full Trade]). Since 'Muddling Through' implies a continuation of currently set legislation with respect to energy demand development as well as CO_2 constraints it reflects a Business as Usual case. In contrast, two themes are developed within the SECURE project, which consider stronger CO_2 constraints policies. The Europe Alone scenario expects that only Europe will care about CO_2 constraints, and hence shows less energy demand in the EU member states accompanied by high CO_2 costs, resulting in high wholesale energy prices. On the other hand, the Global Regime (Full Trade) considers similar CO_2 constraints on a global scale, leading to a little higher energy demand in Europe than in the Europe Alone scenario and shows lower raw energy prices.

Principally, renewable energy sources offer a big potential to improve the security of supply due to domestic energy production on the one hand and their decentralized character on the other. The increased RES deployment due to new installations in the case of strengthened RES support could lead to a reduction in fossil fuel demand of yearly 539 Mtoe by 2030. Oil imports can be reduced by 18 percent, gas imports by 51 percent and coal imports by 68 percent. This will significantly increase the EU's security of supply. In 2030, 150 billion Euro of fossil fuels can be saved, which corresponds to 0.88 percent of GDP. This quantitative assessment is based on the Global Regime (Full Trade) scenario conducted by POLES energy modelling and the monetary figures refer to POLES energy prices. Given the energy prices as recently observed in all markets, saved expenses would still increase compared to the applied price developments. The results show that the 20 percent RES could be achieved at moderate cost, which illustrates the ability of RES to protect the EU economy against rising fossil fuel prices. The financial support provided to increase the support of RES in the coming years should reflect these benefits to EU's supply security.

The Muddling Through scenario only avoids about 267 Mtoe fossil fuels consumption which corresponds to about 78 billion Euro, equalling 0.46 percent of the GDP in 2030. In contrast, the Europe Alone scenario based on strengthened national RES policies, implying improvements of currently implemented policies with respect to efficiency and effectiveness, expects to meet the 20 percent RES target in 2020 and shows the same level of ambition beyond 2020. The Europe Alone scenario only avoids about 540 Mtoe fossil fuels consumption which corresponds to about 146 billion Euro, equalling 0.88 percent of the GDP in 2030. Finally, the Global Regime scenario based on strengthened national policy options foresees to meet the 20 percent RES target by 2020 as well, wherein a continuation of the strong RES deployment is expected to grow until 2030.

Taking into account the lessons learned from the assessment of future renewable energy pathways and the corresponding cost developments, some general conclusions can be drawn here:

Strong growth is needed in all three sectors

A high share of renewable energies in the mid- to long term cannot be reached without strong increases in all three sectors: renewable electricity, heat and biofuels. The future policy framework should address this need for growth in all sectors.

A wide range of technologies has to be supported

Even a policy approach based on pure cost minimization would still need to support a wide range of technologies: large-scale hydropower, solid biomass (for generation of both heat and power) and onshore wind power will be complemented by large amounts of offshore wind power, biogas and small hydropower. Associated costs vary largely between technologies and over time. Consequently, any future policy framework has to address this sufficiently by providing technology specific support to the various RES options.

RES policies should be supported by a strong energy efficiency policy

As also indicated in the comparison of the Europe Alone and the Global Regime (Full Trade) scenario to the Muddling Through scenario, it can be concluded that in the absence of strong energy efficiency policies, energy demand is higher and more RES is required in order to achieve the targeted share of 20 percent by 2020. In that case, more expensive RES technologies have to be utilized and the average yearly transfer costs are expected to largely increase. This underpins the importance of energy efficiency policy and RES policy being used as complementary tools for creating a more sustainable energy system in an economically efficient way.

Endnotes

1. S. Ölz, R. Sims, N. Kirchner. *Contribution of Renewables to Energy Security*, 2007.
2. F. Sensfuß, M. Ragwitz, and M. Genoese. "The Merit-order Effect: A Detailed Analysis of the Price Effect of Renewable Electricity Generation on Spot Market Prices in Germany," *Energy Policy* 36 no. 8 (2008): 3086-3094.

References

- European Commission. 1997. *Energy for the future: renewable sources of energy - White Paper for a community strategy and action plan* . COM (1997) 599 final.
- European Commission. 2000. *Towards a European strategy for the security of energy supply - Green Paper* . COM (2000) 769 final.
- European Commission. 2007. *Renewable energy road map - Renewable energies in the 21st century: building a more sustainable future. Communication from the Commission to the Council and the European Parliament* . COM(2008) 19 final.
- Haas, R.; W. Eichhammer, C. Huber, O. Langniss, A. Lorenzoni, R. Madlener, P. Menanteau, P.E. Morthorst, A. Martins, A. Oniszk, J. Schleich, A. Smith, Z. Vass, A. Verbruggen, A. 2004. How to promote renewable energy systems successfully and effectively. In *Energy Policy*, 32 (6): 833-839.
- International Energy Agency. 2000. *Experience curves for energy technology policy*, Paris: OECD/IEA.
- International Energy Agency. 2008. World energy outlook 2008: OECD/IEA.
- Ölz, S.; R. Sims, and N. Kirchner. 2007. Contribution of renewables to energy security.
- Panzer, C., A. Held, G. Resch, and M. Ragwitz. 2009. Assessment of the potential impact of renewable energy sources on the security of supply, costs of energy security measures and policy support; SECURE deliverable D.5.5.2; http://www.secure-ec.eu/, 2009
- Ragwitz, M.; A. Held, G. Resch, T. Faber, R. Haas, and C. Huber. 2007. OPTRES. Assessment and optimisation of renewable energy support schemes in the European electricity market: Fraunhofer IRB Verl., Stuttgart.
- Sensfuß, F.; M. Ragwitz, and M. Genoese. 2008. The merit-order effect: A detailed analysis of the price effect of renewable electricity generation on spot market prices in Germany. In *Energy Policy* 36 (8): 3086-3094.
- The European Parliament and the Council of the European Union. 2001. *Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market.*
- The European Parliament and the Council of the European Union. 2003. *Directive 2003/30/EC of the European Parliament and of the Council on the promotion of the use of biofuels or other renewable fuels for transport.*
- The European Parliament and Council. 2009. Directive of the European Parliament and the Council on the promotion of the use of energy from renewable sources. Directive 2009/28/EC. Brussels, April 23, 2009.

SECURE Project: Draft Policy Recommendations

There is no easy fix for ensuring long-term as well as short-term security of supply in the EU. Ensuring and improving security of supply requires the implementation of a number of policies and recommendations. This section summarizes the main recommendations put forward by SECURE project partners at the end of three years of joint research activities on these challenging issues.

1. SECURE's Energy Development Scenarios

Between now and 2050, humanity must face two intertwined problems: the growing scarcity of oil (and gas, but not coal) and the accumulation of greenhouse gases (GHG) in the atmosphere.

These "bathtub problems" cannot be considered independently, as hydrocarbon scarcity paves the way to coal (and, hence, higher GHG emissions), while climate policies open the path to low carbon societies. "Smart" energy policies and associated international relations should combine the security, sustainability as well as competitiveness dimensions.

A family of scenarios have been developed in the SECURE project using the POLES model. They illustrate the complex interactions of climate policies and energy security issues:

1. The Muddling Through (MT) scenario describes the consequences of non-coordinated, low profile climate policies;
2. The Muddling Through & Europe plus scenario (MT E+) describes the consequences of non-coordinated, low profile climate policies but with some leadership from Europe;
3. The Europe Alone case (EA) represents the outcome of a scenario in which every country is free-riding ... except the EU;
4. The Global Regime (GR) explores a new world energy system, under strong emission constraint (EU-type).

Scenarios with limited and uncoordinated action for reducing GHGs emissions, such as 'Muddling Through,' imply only weak signals in terms of carbon price, but as they mobilize the cheap part of the Marginal Abatement Cost curves, they already change significantly the level of emissions through reduced demand, accelerated development of non-fossil energy and Carbon Capture and Storage. However, these scenarios do not succeed in meeting the emission targets deemed desirable in the latest IPCC Assessment Report (2007) in order to limit average temperature increase to 2°C above pre-industrial levels.

Scenarios with strong climate policies, such as Global Regime, clearly allow reducing both emissions and the level of tension on international hydrocarbon markets, through lower oil and gas production. This is a double dividend situation, probably the most important one to be derived from ambitious climate policies.

Finally, scenarios with unilateral actions from Europe involving a change of paradigm for the European energy system ('Europe Alone') do not meet the climate target as the impacts of important efforts in Europe are not sufficient to induce massive emission reductions at world level, nor do they limit the risk of energy shocks. However, these scenarios have highly beneficial implications for Europe:

- imposing strong emission reduction domestically results in a thorough restructuring of the European energy system;

- in case of energy shocks, this restructuring will allow Europe to be largely protected by lower energy demand, higher contribution of domestic non-fossil fuels (renewable and nuclear) and a much lower level of fossil fuel imports.

Scenarios that involve no drastic change in Europe's energy system imply the development of the energy security strategy in a conventional setting: the main concern is to ensure that sufficient supply is available, particularly of oil and gas. The Energy Charter that currently provides the basis for this policy is just one of the possible options. The key issue is the possibility of a timely investment for the development of huge production and transport capacities. In that case, the Energy Charter should at least be completed by other policies.

One of the permanent requests of exporting countries is for the importers to ensure the demand security that will guarantee the cost-effectiveness of the supply and transport investments. They also call for the possibility of downstream investment. This type of policy framework would result in some upstream-downstream reintegration of the industries with cross investments in common projects or joint ventures. Based more on bilateral relationships, this type of policy may, however, enter into contradiction with the liberalization and Energy Charter perspectives.

Scenarios that imply a deep restructuring of the European energy sector and energy demand change the market perspectives for the exporters. Demand, when impacted by strong environmental constraints in Europe, will display very different dynamics, in particular after 2030.

If Europe is alone in its efforts to develop a new energy paradigm, then it is highly probable that energy exporters will follow investment profiles that will respond more to the demand dynamics of the other regions. In that case, Europe may be less vulnerable to energy imports if its policy is successful, but more vulnerable in case of failure to implement the new paradigm.

If some kind of global climate regime is implemented, then energy will be more sustainable in the long term, but in the short term there is a risk of producing countries under-investing because of the uncertainties created. This case would provide a very challenging setting for the development of cooperative relations between importer countries and their suppliers. New orientations may encompass economic collaboration on new low carbon technologies or reinforced economic cooperation in areas other than energy.

Scenarios with a new energy paradigm display a lower demand and higher share of non-fossil domestic sources, whether renewable or nuclear. Primary energy demand for oil and coal drops, while gas demand is much less affected.

Total electricity production is almost unchanged in the new paradigm scenarios because electricity is the main carrier of decarbonisation. Moreover, the role of renewable, nuclear and CCS increases with the strengthening of the carbon constraint. Wind and biomass play the major role in the increase of the renewable power plant capacity in Europe.

2. Oil

There is no easy and immediate connection between resource nationalism or political instability and global supply of oil and gas. This is emphatically not because political developments are irrelevant for influencing oil and gas supplies, but because this influence is highly variable and unpredictable. Therefore, political considerations should not be counted as the primary determinants of the oil and gas markets but should be one of the factors that political leaders take into account when they look at those industries.

The existence of conditions of financial stability and growth is crucially important in determining the attitude of producing countries towards the desirable level of production and exports. Financial instability, negative returns on financial assets and protectionism against the oil-producing countries' industrial exports all contribute to support the exporters' view that it is best to keep resources in the ground.

Similarly, expectations about future price levels also influence political attitudes towards production and exports. Aggressive policies aimed at decarbonisation and energy efficiency may have an ambivalent effect: there may be a negative announcement effect, because producers will fear demand destruction and invest less in expanding or maintaining capacity; and a positive market effect, when demand is effectively reduced. Hence, the policy indication is not to entertain policy objectives which cannot realistically be reached, but to emphasize cooperation and pragmatism.

Restrictions of Passage

The most dramatic situation for world oil supply would be the closure of the Strait of Hormuz. The SECURE project's analysis has shown that closing the Strait is not easily accomplished; a good part of the Gulf production could be sent from other ports of the region and the shortage of crude oil could be made up thanks to strategic stocks under the IEA frame. The recommendation is to maintain readiness to reorient oil flows as required. The burden of this task falls primarily on the oil-producing countries. At the same time, it is necessary to maintain the capability to reopen the Strait of Hormuz, in the unlikely event that it might effectively be closed.

The European Union should aim at mitigating the danger of closure of other critical sea lanes which might be caused by navigation accidents through congested passages, the most critical situation being that of the Turkish Straits. An option would be to seek a revision of the Montreux Convention of 1936, to allow for the imposition of size limitations and passage charges on tankers, to discourage free riding and create conditions for the commercial development of pipeline bypasses. The EU should aim at facilitating investment in infrastructure adapted to reduce the danger of accidents and vulnerability, by offering financial incentives and promoting even more stringent regulations for oil and chemical tankers.

Functioning of the International Oil Markets

The unsatisfactory functioning of the international oil markets and the resulting uncertainty and volatility in oil prices is the main security threat for future oil supplies. Price volatility and unpredictability is at the heart of the insecurity that is felt by European citizens and governments, while in fact physical availability, especially for oil, has never been in question. Price volatility and unpredictability discourages investment at all stages of the industry and increases the danger of supply interruptions.

The root cause of price volatility is the rigidity of demand and supply in the short term. These are impossible to change and can only be alleviated through encouraging the accumulation of larger stocks. Increasing the relative weight of trading in real ("wet") oil barrels rather than future paper contracts and their multiple derivatives would improve the situation. This hinges on the will and initiative of major oil-producing countries, but the EU should engage in a dialogue to encourage the adoption of better price discovery methods.

The EU can also move in the direction of shifting the emphasis of price discovery from spot to forward pricing (normally less volatile) by imposing a time lag between the announcement and the implementation of price changes at the retail oil products level. The possibility of a flexible and adjustable price band should also be studied, to avoid price bubbles and/or spikes.

The EU should establish a public agency to invest in larger storage facilities to be offered for use to oil producers (be they national or international oil companies) at low cost. The agency should be empowered to issue certificates convertible in physical barrels: oil deposited into the storage would be exchanged for such certificates, and certificates could be used to withdraw oil from storage. Stored oil certificates should be designed and regulated in such a way that they will be accepted as collateral by financial institutions. The availability of an "oil bank" of this kind would encourage investment in capacity additions in anticipation of demand, thus contributing to more comfortable supply conditions. In this perspective, the role of strategic stocks (which are rarely used and have not prevented or helped in containing major price oscillations), should also be redesigned. Their importance should be revisited in favor of a more flexible policy of encouragement to the accumulation of industry stocks.

Vertical reintegration and reciprocity could also help. Specifically, the national oil companies of major producing countries should be allowed to invest downstream in the European markets establishing their own distribution networks, so as to acquire direct access to the final consumer; in the same way European firms should have the same possibility in producing countries.

3. Natural Gas

Recent times have seen considerable dynamism in the gas market in Europe. Concurrently, there has been a major Ukraine-Russia gas crisis, a collapse in the spot price of natural gas, new European natural gas security of supply regulation, an unprecedented increase in global Liquefied Natural Gas (LNG) supply, and finally, the mass production of natural gas from unconventional sources in the US as a result of technological advancements which had a huge impact on world gas markets.

Security of demand and security of supply are complementary issues in ensuring an overall balance in the security of natural gas supply in the EU. Security of demand requires the EU to provide clearer signals regarding future gas demand in Europe to facilitate investment both internally and externally. A pertinent threat exists in underinvestment in bringing on new supplies by exporters or in the development of necessary new infrastructure due to contradictory estimates in gas demand. The present lack of clarity within the EU and underinvestment would lead to serious security of supply issues in natural gas that could not be solved in the short or medium terms. Therefore, the EU should develop a gas demand forecast which is based on the amalgamation of energy policies and individual national plans.

National and regional differences imply that security of supply levels and mitigation tools will necessarily differ between countries and regions. The Baltic countries and parts of the South East of the EU have significantly lower levels of security of supply and are subject to regional and country-specific circumstances, which call for an overall EU security of supply policy that will allow for adjustment of measures and policies to specific regional circumstances. The model applied in the Baltic Energy Market Interconnection Plan (BEMIP) could be applied for this regional focus, allowing for action with resolve in a certain region.

The process of gas market development and the continued liberalization of the EU's markets are not yet fully realized, and there is a pressing need to go ahead with these measures to ensure long-term security in gas supply. Market structures on the national scale in the EU remain highly concentrated, interconnection projects must be realized, and regulation should be clear and facilitate the market in investments. Furthermore, gas prices in the EU should reflect supply and demand of gas in the long run. Legislation should continuously be reviewed and the goal of creating a fully functioning gas market should be a focal point for legislators both national and in the EU.

EU gas market operators have been shown to invest in markets and not necessarily in security of supply. This means that markets alone will not solve the current issues of low security of supply in some countries, especially where markets are poorly if at all developed, as in the case of Baltic countries. Increasing security of gas supply in these regions is likely to be dependent on government intervention and/or EU regulation.

Further diversification for areas with a current low level of suppliers and routes can be ensured by reverse flow and interconnection as well as new supply routes, both pipelines and LNG. Demand flexibility should be studied further regarding its ability to mitigate security of supply issues in the EU.

The development and strengthening of early warning and crisis prevention mechanisms at the EU level as well as the implementation of regional emergency plans should be encouraged.

Regarding gas transits across Ukraine, the possibility of an independent transmissions operator in the Ukraine composed of Ukrainian, EU, and Russian operators should be seriously evaluated. Such cooperation would significantly enhance security of supply reducing the chances of bilateral disputes affecting gas supply, and additionally ensuring much needed investment in the Ukraine transmission infrastructure.

Although production of unconventional gas in the United States has already had the indirect effect of increasing redirected LNG supply to Europe, the potential of unconventional gas in Europe to significantly impact security of supply is presently unclear, and such resources should only be considered to have a potential impact in the medium to long term. Nevertheless, legislation regarding unconventional gas production should be streamlined and reviewed in order to accompany any potential unconventional gas>s development and to make sure that any lacuna regarding the law of its production is addressed. Additionally, an accurate survey of its potential production in Europe should be generated in order to evaluate its potential impact and provide a degree of clarification about recoverable resources.

With the relevance of traditional suppliers such as Norway and Algeria poised to decline in the midterm, there is a need for Europe to have a robust policy with Russia, but also with the Caspian and Middle East regions, that shows pragmatism, partnership and commitment to their development as gas export partners with Europe as they are expected to play a more important role in European gas supply after 2030.

4. Coal and Carbon Capture, Transport and Storage (CCTS)

The real issue in European steam coal supply security is not resource availability, but rather the absence of an economically and politically sustainable use of coal due to obstacles in the implementation of CCTS. Given the availability of coal, the continuing public financial support to the sector becomes harder and harder to justify.

On the resource side, virtually all major exporters can be considered as "safe" countries in geopolitical terms and no sudden supply disruption on political grounds can reasonably be expected. Short-term supply disruptions may occur due to natural disasters, or due to social tensions, which lead to strikes. Yet, efficient supply management with stockpiling and supply diversification can reduce the short-term risk of disruption for European import countries. Therefore, we suggest that:

- Market monitoring should continue, particularly for developments in specific regions (China)
- Competition authorities should continue to monitor international coal markets, particularly mergers and acquisitions of large coal and mining companies

On the utilization side, there is an implicit supply security threat, i.e. that coal will no longer be an essential element of European energy supply, because the CCTS rollout will be delayed or never carried out. There is justified concern that the ambitious development plans in CCTS demonstration as outlined in the IEA Technology Roadmap over the next decade will not be met. This is based on a lack of determination on the part of public authorities to overcome the significant obstacles inherent in the complexity of the CCTS chain, and the difficulties of the power sector in embracing a technology that challenges the business model of coal electrification. In Europe, the economic use of coal in the power sector and in industry could be threatened. Coal substitution in industrial processes could pose even larger challenges than in electricity production.

Recent estimations find a significant decline in European storage potential and transport infrastructure. Further, increased public opposition to onshore storage will most likely necessitate offshore solutions. This will raise the costs and the technical complexity of the CCTS chain, questioning the role of CCTS as a cornerstone of a strategy to decarbonise European energy systems. The SECURE project therefore recommends that:

- The potential contribution of CCTS to a decarbonised European electricity sector should be reconsidered given new data available on CCTS costs, a better understanding of the complexity of the process chain and the lowered CO_2 storage potential.
- Europe has an important role to play in keeping the technology options open and avoiding premature intellectual property appropriation. The EU co-funded projects should make new knowledge widely available, and a competition between projects should be promoted that yields the highest chances of achieving technical progress.
- The huge and readily available funds for CCTS

should be rapidly deployed. Where industry does not respond, the legal and regulatory framework should be readjusted and the level of incentives should be raised. In the absence of a credible CO_2 price path, forcing utilities into a capture ready option will raise the costs of the standard plants but will not incentivize CCTS investment.

- The strong focus on the implementation of CCTS in the power sector observed in the past should be extended to industry, which can be highly vulnerable to an abandonment of coal. Due to a larger number of small emissions sources, this poses higher challenges to network development.
- Early planning of transport routes is of paramount importance should large-scale CCTS deployment ever become reality. At least in this phase, the state will be needed as a major provider in the development of transportation infrastructure, including planning and siting.
- Construction and operation can be tendered to the private sector, or carried out by state-owned network firms. Routing pipelines along existing networks can lower costs and public rejection. Thus, synergies with other energy network infrastructure (gas, electricity) should be considered.
- Future regulation should specify the allocation and financing principles as well as access for third parties. Sufficient incentives for the private sector to manage the network development are unlikely, given the political, regulatory, technical, and economic uncertainties.
- If Europe fails to fill its role as CCTS pioneer, new strategies for the global roll-out of CCTS are needed. The inclusion of CCTS under the Clean Development Mechanism could help to bring the technology to the markets. However, this would also imply the outsourcing of potential risks associated with the technology.

5. Nuclear

In order to fulfill climate policy goals, nuclear energy may have to play a relevant role in worldwide and EU long-term energy balances. However, according to IEA and EC energy scenarios, the EU nuclear share is expected to halve between now and 2030. As nuclear is presently providing two thirds of all low carbon electricity in the EU, this will create an even larger strain on fulfilling CO_2 targets.

In fact, the so often announced nuclear renaissance is having a difficult birth: With 148 aging reactors in operation in 15 member states, there are presently just four reactors under construction in the EU (one in Finland, one in France, two in Bulgaria). Reasons for the stalling renaissance of nuclear energy are: i- social acceptability (political opposition) for a technology which is perceived as dangerous and for which the permanent waste disposal issue has still not been solved; ii- lack of human capacity (Europe's industrial capacity of building nuclear power plants is said to be limited to maximum four per year; other regions seem to have the same problem of aging workforce) which is expected to worsen over the next years as specialists retire; iii- strongly increasing investment cost for nuclear power due to, among others, improved safety and environmental standards (contrary to the general energy capital cost index which has fallen by 20-30 percent since its peak in 2008, nuclear costs do not seem to have fallen over the last years); iv- technical problems with the new third generation designs of all major manufacturers resulting in huge cost-overruns for the first realizations of the new designs; v- the difficulty to finance hugely capital intensive plants in a market environment and in particular after the financial crises; vi- the increasing uncertainty on construction costs raise some doubts on the ability of nuclear power to foster a decrease in prices.

In this context, government action is essential to:

- promote public debates on nuclear safety, energy security of supply and climate change issues
- guiding investor assurances in licensing procedures
- promote human capital building
- explore regional centers for high-level waste disposal
- clear the position of decommissioning funds
- create a level playing field for low carbon technologies via an effective EU-wide emission trading system and/or carbon tax.

As member states retain sovereignty over energy mixes, local political/public consent and support is vital.

The same high safety standards as for nuclear reactors must be applied to all elements of the associated infrastructure: conversion, enrichment, fuel fabrication, spent fuel storage and reprocessing. Accumulated knowledge and experience, both upstream and downstream, are reflected in existing safety rules. They must be strictly applied in any country using nuclear energy. The EU should put all its geopolitical weight to make sure these rules are respected everywhere and to promote non-proliferation. In fact, a major nuclear accident anywhere in the world will have dramatic consequences also on European nuclear development.

6. Renewable Energy Sources (RES)

In order to decrease import dependency and promote decarbonisation of the European energy system, the increased use of RES should be supported in the electricity, heat and transport sector by means of renewable support policies. Therefore, general recommendations are:

A high share of renewable energies in the mid- to long-term cannot be reached without strong increases in all three sectors: renewable electricity (RES-E), heat (RES-H) and biofuels. The current policy framework in the individual member states does include an extensive set of supporting mechanisms for RES-E and, to some extent, for biofuels, but the current limited and dispersed support for RES-H needs to be addressed in the future. Concerning biofuels, efforts should be directed to develop second generation biofuels.

The general approach should be to keep a level playing field among different technologies, so that most efficient solutions can emerge from market forces, rather than being selected by policy makers.

The present technological uncertainty suggests the need to maintain some public support to a wide range of technologies, at least until the relative merits of different solutions emerge on the basis of solid experience. Consequently, any future policy framework should consider providing technology-specific support to the various RES options. However, this policy should entail periodic reviews of the incentive schemes, in the light of a possible future phasing out.

Efforts to support RES are needed in all member states. The uneven distribution of RES potentials and costs emphasizes the need for intensified cooperation between member states, where suitable accompanying flexibility mechanisms can assist the achievement of national RES targets in an efficient and effective manner.

RES policies should be supported by a strong energy efficiency policy. Modelling results indicate that in the absence of strong energy efficiency policies, energy demand is higher and more RES is required in order to achieve the targeted share of 20 percent by 2020. Consequently, more expensive renewable energy technologies have to be utilized and the average yearly policy costs are expected to increase largely.

To face the challenges resulting from an increased share of fluctuating wind electricity, several potential remedies may be applied:

- Forecasting tools and imbalances management should be improved. Wind power prediction tools enable energy suppliers to forecast the variations of the power outputs which are typical for wind power plants. The implementation of forecasting tools may increase the maximum amount of wind power that can be accommodated in the network.
- Trading at the intra-day market platform would imply a correction of all the imbalances whereas the imbalance payments only apply for the net system imbalances (that, in case of low wind penetration, could be only 50 percent of the total imbalances).
- Storage systems such as pumped-storage hydropower plants, hydro reservoirs, compressed air storage, flywheels or batteries may be used to contribute to managing the integration of fluctuating generation. However, some of the mentioned technological options are not yet competitive in economic terms.
- Smart grids providing intelligent services in addition to its initial purpose of delivering

electricity to the consumers, may contribute to the operation of the electricity system. By enabling intelligent monitoring and an improved control of supply and demand, system reliability and the security of supply can be improved.
- Finally, the reinforcement and, if necessary, the extension of the electricity grid represents one main option of how large amounts of fluctuating electricity can be integrated into the electricity system.

Looking at the longer term, a beneficial political and regulatory framework promoting solar energy imports from North Africa should be created, including options for granting these projects priority status under EU infrastructure projects as well as promoting the development and operation of European and trans-Mediterranean super-grids.

7. Electricity

One of the main barriers to long-term investments in the electricity sector (that usually are quite capital intensive) is regulatory uncertainty: it is fundamental to guarantee investors with some basic key conditions under which they will have to operate, in order to let them correctly assess their risks.

Generation

Electricity generation is a liberalized market, which has proven able to develop in a reasonable way without excessive state interference. However, a monitoring of the adequacy of capacity remains appropriate. To this end, Transmission System Operators (TSOs) should be given the task to determine how much new generation capacity of the different types (e.g. base load, mid-merit, peakers) may be needed to meet the security standards, when and where (the location in the network is very important), having regard to the cost-effectiveness of the proposed solution.

In case public authorities were to identify significant security problems, they could set up incentive/obligation schemes (through instruments such as tendering procedures, capacity payments, capacity markets, etc.) to induce investors to pursue the "optimal" development of the generation set outlined by TSOs. Of course, it is desirable that all this process is coordinated and harmonized at the EU level (by ENTSO-E and ACER) to increase its effectiveness and to avoid market distortions.

Transmission

A significant increase of cross-border transmission capacity is highly desirable. To this end (but also in case of development of intra-national transmission lines), it is necessary:

- to pursue a more stable and harmonized regulatory framework at the European level, under the control of the Agency for the Cooperation of Energy Regulators (ACER);
- to pursue more harmonized, efficient and clear permitting procedures at all administrative levels, requiring the compliance with general framework guidelines; permitting procedures should have a reasonable and mandatory time limit for their duration (e.g. three years);
- to gain social acceptance by clearly stating and quantifying the public benefits of the projects especially from the security of supply, sustainability (in particular when renewable energy flows are involved) and economic points of view. This latter issue is very important to gain consensus: people must know that the realization of the projects will reduce their electricity bills (either by imports of cheaper energy) or by direct compensations; moreover, the strategic importance that characterizes cross-border transmission projects must be highlighted with the support of the highest political decision-making levels.

Regulation should be designed to provide "locational signals", i.e. the spatial (zonal/nodal) differentiation of electricity prices (due to maximum transfer capability constraints and losses on the lines) and of transmission charges (calculated on the basis of how much each agent uses the network). The provision of such signals can lead to a more efficient system operation in the short-term and can promote a more optimized siting of new generators and loads in the long-term.

Distribution

As to the progressive transformation of distribution networks from "passive" to "active" and "smart" networks, cooperation among international, European and national standardization bodies, regulatory authorities, grid operators and manufacturers should be encouraged to further improve open communication protocols and standards for information management and data exchange, to achieve interoperability of smart grid devices and systems and to get rid of technical barrier to their deployment.

From a regulatory point of view, how to support distribution network companies in their investments in such innovative technologies, to ensure that their deployment provides a cost-effective solution to the needs of network users, is a key issue. From this perspective, both incentive and minimum requirements regulation should be based on the quantification, through appropriate indicators, of the effects and benefits of such investments in "smartness."

8. Impacts of Severe Accidents and Terrorist Threat on Energy Security

The energy sector is both a key resource and a critical infrastructure for the economy that forms the backbone of today's society, its goods and services. Therefore, the comparative assessment of accident risks is a pivotal aspect in a comprehensive evaluation of energy security concerns.

Effects of severe accidents and terrorist attacks are interrelated to a variety of other energy security facets including vulnerability to transient or long-term physical disruptions to import supplies, geopolitical dependencies due to imported resources, price fluctuations as a result of single events with extremely large consequences, increased likelihood for accidents due to infrastructure ageing and underinvestment, and enhanced awareness of disasters because of global climate change.

Among centralized large-scale technologies in industrialized countries, estimated expected accident risks are by far the lowest for hydro and nuclear while fossil fuel chains exhibit the highest risks. On the other hand, the maximum credible consequences of low frequency hypothetical severe accidents, which can be viewed as a measure of risk aversion, are by far highest for nuclear and hydro (given high population density downstream from the dam), in the middle range for fossil chains, and very small for solar and wind. For nuclear, the maximum consequences are expected to be strongly reduced for the GEN IV plant compared with GEN III.

Severe accidents affecting energy infrastructure can be costly and can affect other critical infrastructure due to dependencies on energy supply. In most cases, the effects of severe accidents on security of supply are of short-term character due to redundancies. Severe nuclear accidents could cause a long-term problem in electricity supply primarily due to potential secondary effects of such accidents, negatively affecting nuclear energy in general. There are also concerns for hydro, particularly in small countries with relatively few large dams and high dependence on their output.

Decentralized energy systems are less sensitive to severe accidents than the centralized ones.

Allocating appropriate resources for maintaining high safety standards of nuclear power plants and hydro dams is of central importance also for security of supply.

The first-of-its-kind analyses of the terrorist threat by means of scenario quantification for selected energy infrastructure facilities (e.g. oil refinery, LNG terminal, hydro dam, and nuclear power plant) were carried out by the SECURE project. For this purpose, a tool was developed that allows for a quantification of risk, integrates uncertainty assessment, and provides estimates for several consequence categories using a Probabilistic Safety Assessment (PSA) approach. Analysis of uncertainties is of particular relevance because luckily there is no historical experience of extreme scenarios and access to terrorist databases is very limited.

In spite of large uncertainties, the analysis indicates that the frequency of a successful terrorist attack with very large consequences is of the same order of magnitude as can be expected for a disastrous accident in the respective energy chain. This is primarily due to the fact that centralized large energy installations are hard targets and relatively easy to protect, requiring sophisticated attack scenarios to cause significant damage and lasting impacts. Terrorists prefer to attack soft targets that are more vulnerable and may cause a larger number of fatalities.

9. The Demand Dimension of Energy Security

In general, the promotion of a greater end-use energy efficiency should hold the first place in any energy policy, since most actions in this field have a "negative" cost, therefore they are more economically efficient than actions to support RES development and to reduce CO_2 emissions (such as Carbon Capture and Storage technologies). Demand Response should be encouraged, with a rapid and extensive deployment of enabling technologies, such as smart metering. Moreover, Demand Response programs should be designed so as to provide strong (i.e. able to ensure a substantial economic convenience in case of response) signals, as well as be simple and easily understandable by consumers.

SECURE's analysis of the relationship between energy efficiency and energy security, has shown that energy efficiency policies in the EU do work, but there is no silver bullet able to successfully address different policy objectives such as energy security and energy efficiency, unless it is so general that it naturally encompass different sectors and energy uses.

What seems to work is the policy mix: the good news is that currently in Western Europe a policy menu is in place that has produced significant improvements in energy efficiency, has reduced the amount of carbon emissions generated by the economic system, and has contributed to a more secure energy supply for Europe. On the other hand, more fine-tuning and coordination among member states is required in order to reap the potential benefits of enhanced energy efficiency also in terms of energy security. In this sense, the 20-20-20 strategy and, in general, the proactive attitude of the EU in the field of climate change policy could be important opportunities.

This suggests that it would be advisable to continue EU Action Plans and make them binding wherever effective. In this process, differences in the responsiveness of energy consuming sectors to efficiency policies should be taken into account: SECURE's analysis has highlighted, for instance, that mandatory standards for electrical appliances seem to work better for the residential sector, whereas measures supporting information, education and training are more effective in the industrial sector.

Cross-cutting measures, in particular those related to market-based instruments, are those having the strongest influence both on energy security and energy efficiency. From this perspective, it is recommended to consider the development of white certificate market models at EU level. Due account should be taken of successful deployment in some member states.

Demand Response is profitable only if electricity markets are structurally subject to variations, which can be absorbed by the flexibility offered by customers. There are no pre-defined solutions as these hinge on structural conditions. Market design is crucial as it should exploit all the potential of DR; restrictions in flexibility should be clearly analyzed and not discarded for the sake of simplicity.

Network regulation also has an important role, both at the transmission and the distribution level, and, in particular, where there is the interaction with the majority of customers and where a future large deployment of Distributed Generation is possible, which shares a very similar customer base with DR.

Metering, that is, the ability to control and give detailed measures of electricity flows, is the key driver for the implementation of DR.

The role of a public intervention aimed at curbing structural inefficiencies should be evaluated, not only in terms of financial support, but also in terms of creating a market with a clear and stable regulatory framework, in which Europe-wide standardization will reduce the costs of adaptation to national markets.

10. Conclusions

Security of supply should be addressed only within a wider, consistent approach that integrates the other two fundamental pillars of the EU energy policy: sustainability and competitiveness.

"Smart" energy policies must combine these three dimensions without neglecting the international relations context.

European climate policies bring a significant double dividend in terms of reduced vulnerability to energy shocks, even in a non-cooperative framework. But energy scenarios opening the path to low carbon energy systems require an improved framework and incentives for electricity (including renewable) investment, a high degree of integration of the European electricity systems, a favorable institutional and regulatory framework for Carbon Capture Transport and Storage (CCTS), and an objective stance towards nuclear development. In addition to supply policies, demand policies too must be strongly pursued.

Since none of the requisites above are self-evident, and should low-carbon technologies fail to be available in time, the whole transition path to a low carbon economy would be at risk. Governments might thus be required to step in and provide adequate support. The most efficient way for the EU to develop cost-effective low carbon energy use is to have a generalized and viable EU-wide emission trading system capable of delivering standardized carbon prices or an effective EU-wide carbon tax. This is an important example of an area where energy security of supply and market development converge.

Another area where the energy security of supply and the competitiveness dimensions converge is the internal market's development. Integration of markets by developing regulatory policies, which enhance interconnections in gas and electricity infrastructure and thus foster competition, would be a big step in the right direction for European security of supply.

The unsatisfactory functioning of the international oil markets and the resulting uncertainty and volatility in oil prices is seen as the main security threat for future oil supplies because it hinders investment. Measures to reduce this artificially increasing volatility should be envisaged.

Climate policies strongly influence the menu of policy solutions to energy security problems and illustrate the type of uncertainties that the EU and its energy suppliers will have to face in the next decades. Efforts are thus needed to combine institutional solutions with a dialogue with EU's partners on a medium-term programming of investments in the energy sector, in a balanced perspective of mutual understanding.

Gulf Research Center Foundation

Knowledge for All