REDEFINING ENERGY SECURITY FOR THE 21ST CENTURY

An Empirical Analysis of the Evolution of Energy Security Towards Sustainability

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ABSTRACT
The conventional energy security paradigm and the policies that followed emerged in response to the oil shocks of the 1970s. This has led to an unrelenting focus on securing fossil fuels, particularly oil supply from the Middle East region, which holds two-thirds of global oil reserves. The narrow focus on security of supply from regionally concentrated reserves is linked to continued oil dependency and climate change. However, there are fundamental changes now occurring in the global energy system that calls for a rethinking of current energy security perspectives. An analytical framework is developed based on empirical data drawn from the International Energy Agency (IEA), Energy Information Administration (EIA), United Nations, and other international sources to assess these changes including: 1) a shift in energy demand and supply centres away from the OECD towards developing nations, 2) a heightened level of vulnerability and threat from terrorism and other threats upon critical energy infrastructure along with oil market volatility driven by fear of stringent energy supplies; 3) rising geopolitical tension as existing powers and emerging economies compete over less available and concentrated resources; and 4) converging global agendas including sustainable development, climate change and energy security. Based on these findings, this thesis argues that the conventional energy security paradigm is no longer adequate for addressing the increasingly complex and inter-related challenges now confronting the global energy system. A conceptual framework is then proposed for a new energy security paradigm based on sustainability principles, ecological and socioeconomic limits, and international consensus reflected in agreements such as the Kyoto Protocol (1997) and Millennium Declaration (2000). The framework takes an integrated approach demonstrating the interconnections between sustainability and energy security. Conventional energy security strategies both on the demand and supply-side along with geopolitical approaches are assessed from a sustainability perspective. It is argued that energy security policies must remain consistent with this framework to be sustainable and therefore 1) reduce dependence upon regionally concentrated fossil reserves, 2) account for the role that energy plays in broader priorities such as climate mitigation and poverty reduction, and 3) enhance geopolitical cooperation over competition.
EXECUTIVE SUMMARY

Research Problem

Although governments across the world define energy security differently, it typically means ensuring a reliable supply of energy resources at reasonable prices to support economic growth (Suzuki et al. 1998; Von Hippel 2004; Helm 2005; Dorian et al. 2006; Gupta & Jaswell 2006; UNECE 2006; Yergin 2006). In the pre-World War II era, energy, particularly oil was considered a strategic material since it powered the military having direct implications for national security. The oil price shocks of the 1970s reaffirmed the importance of oil as a national security interest shaping the modern energy security paradigm that exists today. During the 1980s however, oil lost its importance as a strategic material and came to be viewed as a commodity due to the rise of the international market, low crude oil prices and the collapse of the Cold War structure (O’Brien 1997; Suzuki et al. 1998; JFIR 2006; Toichi 2006). In recent years, energy security has risen back to the top of the international political agenda. The renewed focus on energy security is driven by increasing global energy demand, the prospect of dwindling supplies, the doubling of oil prices in recent years, investment constraints, political instability in exporting countries, the threat of terrorism, geopolitical rivalry and growing energy dependency among major powers. Most importantly, the recent upward trend in world traded oil prices has highlighted the tight balance between increasing oil demand and declining production capacity driven by unrelenting economic growth in China, India and other developing countries (Birol 2006; EIA 2006; IEA 2006a; Kowalski 2006). What further compounds the above issues is that energy security has re-emerged as a policy concern at the same time climate change and sustainable development have become overarching international priorities. These new policy initiatives are likely to become increasingly important as energy demand continues to rise driven by population growth and rapid industrialization in developing countries (Helm 2005). The global energy security situation appears to be more volatile and uncertain than ever (Birol 2006; EIA 2006; IEA 2006a; Kowalski 2006).

The current debate is whether the recent upward trend in oil prices are merely part of a cycle and will stabilize in time or, whether recent events reflect deeper structural changes which could be characterized as a paradigm shift in the global energy security system (Helm 2005; Evans 2006; JFIR 2006; Toichi 2006; Yergin 2006, 2007). For example, the traditional focus areas of the conventional energy security system that arose in response to the oil shocks of the 1970s include: supply sources, demand centres, market structures, institutional responsiveness and geopolitics. These areas form the core of national and international debate over how best to ensure economies are not jeopardized by insufficient energy supply. However, an awareness of the strategic importance of energy has re-emerged with governments applying strategic planning to energy issues. This has two important implications: 1) national interests may start colliding in the international energy market, and 2) confrontations may become further complicated by converging global issues such as diplomacy, defence, economy and trade, and environment (JFIR 2006; Toichi 2006).

Therefore, a broader approach to energy security may now be required accounting for the globalization of energy trade, supply-chain vulnerabilities, terrorism, and the integration of major new economies such as, China and India into the world market (Yergin 2006). It must also be recognized that energy security is not an isolated concept, but is embedded within the larger relations between nations. As such, the conventional paradigm of energy security, which arose from the 1970s, may no longer be sufficient, calling for a new understanding of the risks, impacts and potential solutions that comprise and ultimately address energy security in the 21st century. It is possible that the current paradigm shift is of sufficient magnitude for a recasting of energy policies to account for a new set of global priorities.
Redefining Energy Security for the 21st Century
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(Helm 2005; JFIR 2006; Toichi 2006). Suzuki et al. (1998) have indicated that the concept of energy security needs to be expanded to include: 1) environment, 2) technology, 3) demand-side management, 4) social and cultural factors, and 5) post-Cold War international relations, in addition to the conventional focus on supply-side security. A fundamental shift in the global energy security paradigm bears upon governments around the world to re-evaluate what may now be outdated energy security policies (Suzuki et al. 1998; Helm 2005; JFIR 2006; Toichi 2006; Yergin 2006; WEF 2006; Yergin 2007).

Increasing complexity, interdependency and uncertainty surrounding the current energy security system can be captured by four overarching domains illustrated in Figure 1-4. The broken boundary lines of each domain show that there is a high level of uncertainty and change within each domain compounded by complex interactions with each other shown by interlinking arrows. The higher intensity of the broken boundary line of the energy security domain illustrates that it is being influenced by the other domains causing stress and uncertainty. These domains form an analytical framework to view, assess and understand the rapid and unprecedented changes now confronting the global energy system and how this may require a new perspective of energy security.

Figure 1. Complexity, Interdependency and Uncertainty Surrounding the Conventional Energy Security Paradigm

These key features constitute a fundamental shift in the global energy security paradigm from the one that emerged in the post 1970s era. This has significant implications for how governments pursue both national security and foreign policy agendas in the pursuit of energy. Energy policies are now being challenged on multiple fronts and the substance of these challenges needs to be incorporated into a new concept of energy security (Von Hippel 2004). The following hypothesis is therefore posited:
Hypothesis

The conventional energy security paradigm is no longer adequate for addressing the increasingly complex and interconnected challenges facing the current global energy system. A new concept of energy security is therefore required, which accounts for new and converging global priorities including climate change and sustainable development.

The hypothesis is examined by the following three research questions:

Research Question 1.

What are the driving forces behind the conventional energy security paradigm? How did the concept evolve and what implications does it have for energy security issues today and into the future?

The Conventional Energy Security Paradigm: Root Causes & Current Implications

Energy security policy has traditionally focused on Middle Eastern oil for the following key reasons: First, although the global market share of oil is expected to decrease over time (39% in 2003 to 33% in 2030) it will remain the world’s dominant fuel (EIA 2006). Second, the Middle East holds the world’s largest oil reserves and is considered to be one of the most politically unstable regions in the world. Third, oil supply and prices can be influenced by political and military motives. Fourth, the global economy is vulnerable to oil price volatility particularly, for oil dependent nations and key sectors such as transportation, petrochemicals and the military (Suzuki et al. 1998; World Bank 2002; Yergin 2006).

Oil security has thus been a major concern for both oil importing and exporting economies since the first oil price shocks of the 1970s (McDonald et al. 2005).

The oil crises of 1970s heightened the perceived vulnerabilities of oil importing nations to the interplay between oil prices, Middle Eastern politics and macroeconomic impacts. The modern energy security paradigm emerged as a response mechanism to the perceived threat that these factors posed for industrialized nations if one of them were to go out of balance. However, empirical data indicates that making a definitive link between oil market volatility, Middle Eastern political events and macroeconomic effects upon the industrialized world is far from conclusive for the following three central reasons: 1) In recent years, a confluence of inter-related factors have led to the recent increase in oil prices, 2) there is uncertainty surrounding the precise dynamics, pathways and effects of oil shocks upon the macro economy and 3) the market has a great deal of potential to mitigate the effects of oil supply and price disruptions. Nevertheless, modern energy security has come to mean stabilizing the Middle East through foreign policy or, military intervention to reduce vulnerability to oil price shocks and supply disruption. These assumptions have motivated military intervention by industrialized nations into most of the world’s oil producing regions. Indeed, conventional energy security policies, with their central focus on securing oil supply have done little to reduce oil dependency therefore increasing the vulnerabilities that they are designed to mitigate.

Along with military projection the other central implications of the modern energy security paradigm are disproportionate impacts borne by developing nations due to oil market volatility and climate change. Among the world’s foremost challenges are mitigating the threat of climate change while addressing the rise of Greenhouse Gas (GHG) emitting fossil fuel consumption. Climate change has profound implications for international security and human well-being. An energy security system based on fossil fuel dependency is already the cause of sustained human conflict. This combined with the direct contribution to climate change calls for a fundamental shift towards a more sustainable
energy system. The energy security paradigm needs to evolve to engender policies that respond to these challenges rather than perpetuate them.

Research Question 2.

What are the central features of a structural shift in the global energy security paradigm and what implications does this have for a new conceptualization of energy security?

Tracing the Structural Shifts of the Modern Energy Security Paradigm

Fundamental shifts in the modern energy security paradigm are occurring and can be characterized as: 1) a shift in energy demand and supply centres away from the Organization of Economic Development (OECD) countries towards developing nations, 2) a heightened sense of vulnerability from terrorism and other threats upon critical energy infrastructure and market volatility driven by fear of stringent energy supplies; 3) rising geopolitical tension as existing powers and emerging economies compete over less available and concentrated resources; and, 4) the convergence of new global priorities such as sustainable development and climate change (Table 1). These fundamental changes are placing immense stress upon the global energy system forcing a reconceptualization of what energy security means in the 21st century.

Table 1. Summary of Key Features of a Shifting Energy Security Paradigm

<table>
<thead>
<tr>
<th>Key Features</th>
<th>Driving Forces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Shifts in Demand &amp; Supply</td>
<td>Demand and supply centres are shifting away from OECD countries towards non-OECD nations driven by increasing demand from China and other Asian economies and a growing concentration of supply production in the Middle East and North Africa (MENA). This shift in supply centres is caused by declining production capacity in OECD countries and comparative economic advantage to develop new resources in MENA countries. The shift in demand is being caused by unprecedented economic growth led by energy intensive industrialization in China, India and other developing countries. As a result, rising global energy demand versus declining production capacity is causing heightened anxiety over long-term supply stringencies. A number of factors are influencing this anxiety including oil market volatility, the debate over oil peaking and both upstream and downstream investment constraints.</td>
</tr>
<tr>
<td>Rising Vulnerability &amp; Threat</td>
<td>A central threat to energy security is oil market volatility. This is compounded by the heightened perception of risk placing upward pressure on oil prices. The perception of increased risk is driven by the potential threat of terrorism and increased vulnerability as energy supply chains integrate and become increasingly complex. Supply chains are crossing more remote areas and passing through vulnerable geographic “chokeholds”. As the global energy system becomes more interconnected, vulnerabilities in the system are exposed to acts of terrorism, extreme weather events and accidents. The perception over increased vulnerability is also linked with geopolitical competition over increasingly concentrated resources causing a tight demand/supply situation. Increased risk perceptions are passed onto the markets as higher prices contributing to oil market volatility thus causing a positive feedback loop.</td>
</tr>
</tbody>
</table>
### Key Features

<table>
<thead>
<tr>
<th>Driving Forces</th>
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<tr>
<td>Closely linked to shifting demand-supply centres is growing geopolitical tension in the world’s major oil producing regions such as the Middle East, Central Asia and Latin America. What is driving this is the growing energy dependency among the world’s major powers, most notably the United States and Europe, upon potentially unstable regions. As production capacity declines in OECD countries and resources become more scarce geopolitical competition over regionally concentrated resources may increasingly be a feature of the global energy market. The strained relation between China and Japan over east Siberian oil is one recent example, and a potential confrontation between the world’s two largest oil consumers the US and China may become a reality.</td>
</tr>
<tr>
<td>All the above issues are further complicated by converging global agendas and new priorities taken on by the international community most notably sustainable development and climate change. As a result, powerful national, regional, corporate and civil interests may continue to collide as international energy markets further integrate and foreign policy, national defence, economic and trade, and environmental issues become deeply entangled.</td>
</tr>
</tbody>
</table>

Sources: Adapted from Helm 2005; Deutch & Schlesinger 2006; Evans 2006; IEA 2006a; JFIR 2006; Koakutsu & Watanabe 2006; Toichi 2006; WEF 2006; Yergin 2006, 2007

These key features arguably constitute a fundamental shift in the global energy security paradigm from the one that emerged in the post 1970s era. If a paradigm shift is occurring, this implies that current energy security policies may no longer be adequate with important implications for how governments define both national security and foreign policy agendas in the pursuit of energy.

Research Question 3.

What would a new energy security paradigm look like and how would it account for new global priorities including climate change and sustainable development?

### Evolving a Conceptual Framework for Sustainable Energy Security

In order to protect natural life-support systems and eradicate energy poverty in developing countries a transformation towards a more sustainable energy system is required. A crucial aspect of this reconfiguration is the promotion of global peace by reducing dependency upon regionally concentrated oil reserves and shifting away from a fossil based society (WBGU 2004). What this implies is that in the context of energy security the fourth dimension of geopolitics needs to be added to the original three dimensions of sustainability (Figure 2). Most importantly each dimension is interlinked where actions in one sphere have repercussions on the other. The interconnections between these spheres of activity are reflected by the growing convergence of climate change, sustainable development and energy security as global priorities. Integrated strategies that account for each sphere of activity and how they interact will need to be taken in order to achieve a sustainable energy security system. This means that the development and implementation of energy security policies and strategies should be consistent with the principles of sustainability.
A conceptual framework for assessing and developing energy security strategies from a sustainability perspective is shown in Figure 3. The largest domain indicates the guiding principles of energy sustainability most importantly equal access to basic energy services; the second domain are ecological and socioeconomic upper bound limits based on the German Advisory Council for Global Change’s concept of “Guardrails” for sustainable energy systems (WBGU 2004) and complemented by energy indicators developed by the International Atomic Energy Agency (IAEA 2005). These metrics provide a reference point for evolving energy security strategies and should not be compromised if sustainability is to be realized; the third domain are political declarations and international commitments to energy sustainability and understanding over the role that energy plays in poverty reduction. Among the most important international agreements are the Energy Charter (1992), the UNFCCC’s Kyoto Protocol (1997) and the Millennium Declaration (2000). The last domain represents national or, regional strategies to ensure energy security, which should conform to and reflect all other domains if they are to be sustainable.

Energy security strategies can be taken on the supply-side and demand-side, while a third crucial aspect involves geopolitical relations. On the supply-side, key measures include reducing fossil fuel import dependence and diversifying primary energy sources. The principle of diversification can also be applied to suppliers, technologies, transport routes and infrastructure based on the assumption that a distributed and diversified energy system is less vulnerable to large threats than centralized systems. On the demand side, improving energy efficiency and conservation can reduce primary energy requirements therefore lowering energy dependency. More conventional strategies include building up strategic oil reserves, accelerating exploration for new fossil reserves or, increasing infrastructure investments. Due to a globalizing energy market and integrating supply-chains, rising energy interdependence is becoming an important catalyst for enhancing security. Interdependence points to the need for improved geopolitical relations between nations as this can influence all other demand or supply-side strategies. This implies that geopolitical cooperation should be pursued through multi-lateral concensus building rather than conventional foreign policy strategies such as geostrategic competition and military projection.
What the sustainable energy security framework implies is that all these potential strategies must be viewed and assessed from a broader perspective, extending far beyond the traditional view of security of supply. In doing so, the formulation of energy security strategies must recognize the direct links between meeting the needs of economic growth, contributing to a better quality of life, protecting the environment (WEA 2004) while enhancing geopolitical relations rather than compounding rivalries.

The conventional energy security paradigm and the strategies and polices that have arisen from it have perpetuated society’s reliance on fossil fuels bringing into conflict the interrelated goals of enhancing energy security, mitigating climate change, alleviating poverty and increasing geopolitical stability. The central contribution of a new energy security paradigm based on sustainability is that it addresses the complex challenges of energy security in an integrated manner bringing renewed focus to energy diversification and efficiency, pursue policies to reduce demand for fossil fuels with an aim to eliminate oil dependency altogether, particularly in developing nations where impacts are felt the hardest, and stimulate a serious reconsideration about the viable contribution that renewables can make to security of supply. The convergence of global priorities reflected by international commitments such as the Kyoto Protocol, Millennium Development Goals and Energy Charter constitute the need for a fundamental shift in how energy security is perceived and pursued in the 21st Century.
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1 INTRODUCTION

Energy security has re-emerged on the international political landscape claiming centre stage at the G8 2006 Summit in St. Petersburg Russia. Recent global events have highlighted increasing uncertainty surrounding the global energy system. A globalizing energy market, surges in oil prices, geopolitical tension, the threat of terrorism, infrastructural constraints and climate change are now key drivers behind the energy security debate. Growing uncertainty over these increasingly complex issues are forcing governments to re-evaluate what energy security means in the 21st Century. This thesis challenges the basis of the conventional energy security paradigm and asserts that it is no longer adequate for addressing the inter-related issues now facing the current global energy system. The central premise of this thesis is that commonly held perspectives and norms result in a certain course of actions. And if the objective is to change that course of action, the underlying perception must first be changed. In doing so, this thesis will first show how the conventional energy security paradigm has led down a path of actions that are no longer desirable or indeed acceptable; it will then demonstrate with empirical evidence that the current energy system is undergoing rapid and unprecedented change calling for a new perspective of energy security; finally, the first elementary steps of a conceptual framework is then proposed for what energy security policies will have to entail to respond to the challenges of the 21st Century.

1.1 Objectives

The objectives of this thesis are:

➤ To identify a relevant research problem within the energy security field.

➤ To frame a hypothesis to address the research problem.

➤ To develop and implement an analytical framework to explore the hypothesis.

➤ To contribute to the state of knowledge of energy security by addressing the identified research problem.

➤ To develop a novel approach to address or at least partially resolve the research problem and establish the basis for further research.

1.2 Scope & Limitations

The scope of this research is confined to the methodological approach discussed in section 1.3 and research problem discussed in Section 1.4. The specific limitations of this research are as follows:

Methodological Limitations

➤ This thesis is primarily based upon secondary data sources. Primary qualitative input was provided only in the form of informal discussions to evolve the research concept. No attempt was made to gather a representative survey sample size for analysis, as this was not required to achieve the research objectives. The analysis relies upon quantitative empirical data drawn from academic literature and on-line databases of internationally recognized sources including the International Energy Agency (IEA), Energy Information Administration (EIA), International Monetary Fund (IMF), United Nations, Asian Development Bank (ADB) and others. Although triangulation of secondary data was consistently applied, no first hand verification of data was conducted since
original data sets were not obtained. As a result, heavy reliance is given to the assumed quality of secondary quantitative data.

➤ Establishing a problem context and hypothesis research framework necessarily confines the selection of data and analysis relevant to the hypothesis. As a result, other important issues may be overlooked. However, a reasonable attempt was made to assess a broad cross-section of the most up to date and concurrent information (See Bibliography).

Analytical Limitations

➤ Analysis is generally confined to the macro-level, although site-specific examples are drawn upon for expository purposes or to support a line of argumentation.

➤ Empirical macroeconomic data was selected to support a specific line of argumentation that challenges the direct link between Middle Eastern political events, oil market volatility and macroeconomic effects upon industrialized countries. Although counter-arguments are clearly stated, less overall coverage is afforded to them. This does not compromise the analysis since only one valid incidence of empirical evidence is required to prove the argument that there is not a definitive link between cause and effect. Conversely, it would take an infinite amount of empirical evidence to prove a definitive link.

➤ Less attention is given to gas markets along with unconventional fossil sources such as tar sands, shale sands, etc. deferring primarily to oil markets. Reasons for this are provided in section 2.4 and 2.5.

➤ Discussion of oil externalities is confined to energy security policies in the context of military expenditure. Other externalities related to oil dependency are only touched upon.

➤ The central role of corporations and national oil companies (NOCs) has not been addressed.

➤ Analysis of the role of energy technologies was not conducted.

➤ Sectoral level analysis of energy demand was not conducted.

1.3 Methods

Step 1. Concept Evolution & Exploratory Discussions: Weeks 1-8

From March to April 2007 a site visit was conducted to Thailand and Vietnam to engage various resource persons in the energy field. Informal discussions were held with representatives from the following organizations: Energy and Petroleum Department, Vietnam Ministry of Industry (MOI), Vietnam National Office for Climate Change and Ozone Protection Centre (NOCCOP), Carl Bro International, United Nations Development Programme Vietnam, United Nations Development Program Regional Office for Asia and the Pacific, Stockholm Environment Institute (SEI), Asian Institute of Technology (AIT), Research Centre for Energy and Environment (RCEE), SNV World, Netherlands. The overall objective was to gain first hand qualitative understanding about the various challenges surrounding energy initiatives in the developing nations context in relation to sustainable development and climate change. There was no attempt to explicitly integrate these discussions into this thesis, rather the discussions served as brainstorming sessions to evolve the concept of energy security as an overarching systemic analytical framework to encompass the myriad issues now confronting the global energy system.
Informal discussions were held over the course of 2 months comprising approximately 40 hours of direct communications with key resource persons (Appendix 1) concerning energy development, sustainability and security from a variety of perspectives. Figure 1-1 depicts the range of energy issues and topics that were discussed showing how exploratory discussions eventually coalesced around the central topic of energy security, leading to the question of whether it could be used as an overarching analytical framework.


demand and supply centres  
Oil volatility, peaking, dependency  
Supply disruptions  
Energy markets  
Investment needs  
Infrastructure constraints  
Geographic chokeholds

Geopolitics  
Terrorism  
Military projection  
Foreign diplomacy  
Energy poverty  
Sustainable development  
Climate change
Step 3. Problem Identification: Week 9-10

Triangulation of literature sources was conducted to define a relevant and up-to-date research problem confronting the energy security field. Expert opinions were assessed from secondary sources and cross-referenced with the trend analysis to determine if the research problem could be assessed with empirical data. Figure 1-2 illustrates the triangulation method used to identify a relevant research problem. The broken lines of a circle indicate less certainty over an issue but when brought together with different sources that point to the same issue, raises the overall level of certainty and clarity illustrated by the solid black line of the triangle.

Figure 1-2. Triangulation Method to Identify Problem Issue

Triangulation increased the level of confidence over the relevance of the research problem. In doing so, a critical mass of understanding was reached in order to formulate a hypothesis to address the identified problem. Research questions were then defined to further guide the research process.


The original list of issues identified from the scoping analysis was revisited and looked at from the point of view of the research problem. From the array of issues emerged a pattern shown in Figure 1-3. Four overarching domains emerged that could capture in one-way or another the broad range of energy security issues in relation to the research problem. These domains include energy demand and supply centres, geopolitical tension, vulnerability and threat and converging global agendas. These four domains form the analytical framework used to examine the hypothesis. The analysis was done in two steps: 1) assessing the individual but inter-related factors that fall within each domain and 2) assessing how each domain influences and interacts with the other (illustrated by interlinking arrows).
These key domains are described in Section 1.4. It is argued that activities within and between each domain are causing rapid and unprecedented changes in the global energy system constituting a shift in the conventional energy security paradigm, which underpins the central hypothesis of this research (Section 1.5). In order to examine the hypothesis, a baseline or reference point was established by characterizing the conventional energy security paradigm from an evolutionary or historical perspective (Section 2). This baseline is then used to compare against the rapid changes that are now occurring in the global energy system (Section 3).


A conceptual framework was then developed for assessing and evolving energy security strategies from a sustainability perspective. The framework is based on four conceptual domains. The first domain is sustainability principles applicable to energy systems drawn from well-established international declarations and concepts of sustainability such as the Brundtland Report (WCED 1987).

The second domain consists of quantitative and qualitative metrics and indicators setting ecological and socioeconomic boundaries for sustainable energy development. Metrics and indicators are drawn from two well established sources: 1) the German Advisory Council on Global Change (WBGU) and 2) the International Atomic Energy Agency (IAEA) in association with the United Nations Department of Economic and Social Affairs (UNDESA), the International Energy Agency (IEA), Eurostat and the European Environment Agency (EEA). Coverage of indicators and metrics are descriptive not analytical. The metrics and indicators however are brought together in a novel way to form a composite measure for developing and assessing energy security policies.

The third domain refers to international commitments and political declarations for sustainable development, climate change and energy trade. They are presented to demonstrate the international consensus over the sustainable use of energy. It is proposed that any energy security strategy or policy should conform to these international commitments.
The last domain is a synthesis of energy security strategies, which are assessed in reference to the previous domains from a sustainability perspective. Energy security strategies are broadly grouped into supply and demand-side strategies along with geopolitical approaches. The basic conceptual framework is shown in Figure 1-4 followed by a flowchart of the methodological approach which shows how findings from each research step builds upon the next and is brought to bear upon the final analysis of energy security strategies.

Figure 1-4. Conceptual Framework for Sustainable Energy Security Strategies
Methodological Approach

**Step 1. Concept Evolution - Exploratory Discussions**
- Focus discussions with 14 energy professionals to develop conceptual basis for thesis. Approximately 40 hours of direct communications and continued dialogue over the course of 2 months via email, phone.

**Step 2. Empirical Trend Analysis**
- Literature review and empirical data compilation.
- Identification of key issues, trends, drivers.
- Verification of trends and drivers with quantitative data (i.e. energy demand and supply projections, investment needs, etc.).

**Step 3. Research Problem Identification**
- Determine relevant and up to date research problem through triangulation of expert opinions from literature with empirical trend analysis from Step 2.
- Critical mass of understanding achieved to formulate hypothesis and research questions.

**Step 4. Development & Implementation of Analytical Framework**
- Reassess key issues and trend analysis from point of view of the research problem and develop analytical framework
- Implement analytical framework through 1) historical characterization of conventional energy security perspectives and, 2) assess current shifts in the global energy security system based on: i. shifts in demand and supply ii. Vulnerability and threat iii. Geopolitical tension iv. Converging global agendas.

- Develop conceptual framework based on 1) sustainability principles, 2) upperbound limits using ecological and socioeconomic metrics 3) international commitments and declarations, 4) energy security strategies.
- Analysis of energy security strategies based on sustainability framework and integration of findings from previous research step. Determine contribution of sustainable energy security framework and identify research gaps.
1.4 Research Problem

Energy security is back on top of the political agenda. The renewed focus on energy security is driven by increasing global energy demand, the prospect of dwindling supplies, the doubling of oil prices in recent years, investment constraints, political instability in exporting countries, and the threat of terrorism, geopolitical rivalry and growing energy dependency among major powers. Most importantly, the recent upward trend in world traded oil prices has highlighted the tight balance between increasing oil demand and declining production capacity. Moreover, unrelenting economic growth in China, India and other developing countries is straining an already tight supply situation. The global energy security situation appears to be more volatile and uncertain than ever (Birol 2006; EIA 2006; IEA 2006a; Kowalski 2006). The following questions are now foremost among policy makers today: 1) Is the world running out of oil? 2) Where will future energy supplies come from? 3) Will adequate infrastructure investment be made to meet future demand? 4) What role will governments and the market play? These questions reflect the growing uncertainty over where the global energy system is headed and what implications this has for nations of the world today and into the future (Helm 2005; Birol 2006; EC 2006; Giusti 2006; G8 2006; Kowalski 2006; WEF 2006; Yergin 2006).

One of the central challenges in the energy security debate is that energy security means different things to different countries – perspectives are diverse and complex: importing countries primarily focus on securing supply; oil exporting countries focus on maintaining long-term demand; producers with large reserves are often interested in moderating prices to maintain their market over the long-term, while other producers with smaller reserves may try to maximize short-term returns; some consumers and producers support market forces to work freely, while others desire government intervention to moderate prices or guarantee access to supplies. In other words, energy security issues are increasingly complex and uncertainties abound. What is certain however is that oil prices, international markets, and energy policies are converging into a renewed debate over what constitutes energy security in the 21st century (Suzuki et al. 1998; Giusti 2006).

In the pre-World War II era, energy, particularly oil was considered a strategic material since it powered the military and therefore had direct implications for national security. The oil price shocks of the 1970s reaffirmed the importance of oil as a national security interest shaping the energy policies that exist today. During the 1980s however, oil lost its importance as a strategic material and came to be viewed as a commodity due to the rise of the international market, low crude oil prices and the collapse of the Cold War structure (O’Brien 1997; Suzuki et al. 1998; JFIR 2006; Toichi 2006). As a result, the focus on energy security policies became less important for governments as the commodity era of the 1980s ushered in a consistent worldview that favoured privatization, liberalization and the removal of trade restrictions. However, security of supply has now re-emerged as a policy concern at the same time climate change has become an overarching priority with new government interventions and market mechanisms including carbon-related taxes, emissions-trading schemes and subsidies. These new policy initiatives are likely to become increasingly important as energy demand continues to rise driven by population growth and rapid industrialization in China, India, and other developing countries. The cumulative effects of these various factors in recent years may constitute a structural break in the energy security paradigm comparable to the one that arose after the OPEC oil shocks of the 1970s, which ushered in the privatization, competition and liberalization agendas of the 1980s.

The world today however, is significantly different from that of the 1970s and 80s. The current debate is whether the recent upward trend in oil prices are merely part of a cycle and will stabilize in time or, whether recent events reflect deeper structural changes which could be characterized as a paradigm shift in the global energy security system (Helm 2005; Evans 2006; JFIR 2006; Toichi 2006; Yergin 2006, 2007). The traditional focus areas of the conventional energy security system include: supply sources, demand centres, market structures, institutional responsiveness and geopolitics. These areas form the core of national and international debate over how best to ensure economies are not jeopardized by insufficient energy supply. However, an awareness of the strategic importance of energy has re-emerged with governments applying strategic planning to energy issues. This has two important
implications: 1) national interests may start colliding in the international energy market, and 2) confrontations may become further complicated by converging global issues such as diplomacy, defence, economy and trade, and environment (JFIR 2006; Toichi 2006). A broader approach to energy security may now be required accounting for the globalization of energy trade, supply-chain vulnerabilities, terrorism, and the integration of major new economies such as, China and India into the world market (Yergin 2006). It must also be recognized that energy security is not an isolated concept, but is embedded within the larger relations between nations. As such, the conventional paradigm of energy security, which arose from the 1970s, may no longer be sufficient, calling for a new understanding of the risks, impacts and potential solutions that comprise and ultimately address energy security in the 21st century. It is therefore possible that the current structural break is of sufficient magnitude for a recasting of energy policies to account for a new set of global priorities (Helm 2005; JFIR 2006; Toichi 2006). For instance, Suzuki et al. (1998) have indicated that the concept of energy security needs to be expanded to include: 1) environment, 2) technology, 3) demand-side management, 4) social and cultural factors, and 5) post-Cold War international relations, in addition to the conventional focus on supply-side security. A fundamental shift in the global energy security paradigm bears upon governments around the world to re-evaluate what may now be outdated energy security policies (Suzuki et al. 1998; Helm 2005; JFIR 2006; Toichi 2006; Yergin 2006; WEF 2006; Yergin 2007).

Increasing complexity, interdependency and uncertainty surrounding the current energy security system can be captured by four overarching domains illustrated in Figure 1-4. The broken boundary lines of each domain show that there is a high level of uncertainty and change within each domain compounded by complex interactions with each other shown by interlinking arrows. The higher intensity of the broken boundary line of the energy security domain illustrates that it being influenced by the other domains and is under the most stress and uncertainty. These domains form an analytical framework to view, assess and understand the rapid and unprecedented changes now confronting the global energy system and how this may require a new perspective of energy security. Table 1-1 summarizes the driving forces behind each domain acting upon the energy security system.

Figure 1-5. Complexity, Interdependency and Uncertainty Surrounding the Conventional Energy Security Paradigm


Table 1-1. Summary of Key Features of a Shifting Energy Security Paradigm

<table>
<thead>
<tr>
<th>Key Features</th>
<th>Driving Forces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Shifts in Demand &amp; Supply</td>
<td>Demand and supply centres are shifting away from OECD countries towards non-OECD nations driven by increasing demand from China and other Asian economies and a growing concentration of supply production in the Middle East and North Africa (MENA). This shift in supply centres is caused by declining production capacity in OECD countries and comparative economic advantage to develop new resources in MENA countries. The shift in demand is being caused by unprecedented economic growth led by energy intensive industrialization in China, India and other developing countries. As a result, rising global demand versus declining production capacity is causing heightened anxiety over long-term supply stringencies. A number of factors are influencing this anxiety including oil market volatility, the debate over oil peaking and both upstream and downstream investment constraints.</td>
</tr>
<tr>
<td>Rising Vulnerability &amp; Threat</td>
<td>A central threat to energy security is oil market volatility. This is compounded by the heightened perception of risk placing upward pressure on oil prices. The perception of increased risk is driven by the potential threat of terrorism and increased vulnerability as energy supply chains integrate and become increasingly complex. Supply chains are crossing more remote areas and passing through vulnerable geographic “chokeholds”. As the global energy system becomes more interconnected, vulnerabilities in the system are exposed to acts of terrorism, extreme weather events and accidents. The perception over increased vulnerability is also linked with geopolitical competition over increasingly concentrated resources causing a tight demand/supply situation. Increased risk perceptions are passed onto the markets as higher prices contributing to oil market volatility thus causing a positive feedback loop.</td>
</tr>
<tr>
<td>Heightened Geopolitical Tension</td>
<td>Closely linked to shifting demand-supply centres is growing geopolitical tension in the world’s major oil producing regions such as the Middle East, Central Asia and Latin America. What is driving this is the growing energy dependency among the world’s major powers, most notably the United States and Europe, upon potentially unstable regions. As production capacity declines in OECD countries and resources become more scarce geopolitical competition over regionally concentrated resources may increasingly be a feature of the global energy market. The strained relation between China and Japan over east Siberian oil is one recent example, and a potential confrontation between the world’s two largest oil consumers the US and China may become a reality.</td>
</tr>
<tr>
<td>Converging Global Agendas</td>
<td>All the above issues are further complicated by converging global agendas and new priorities taken on by the international community most notably sustainable development and climate change. As a result, powerful national, regional, corporate and civil interests may continue to collide as international energy markets further integrate and foreign policy, national defence, economic and trade, and environmental issues become deeply entangled.</td>
</tr>
</tbody>
</table>

Sources: Adapted from Helm 2005; Deutb & Schlesinger 2006; Evans 2006; IEA 2006a; JFIR 2006; Koakutsu & Watanabe 2006; Toichi 2006; WEF 2006; Yergin 2006, 2007

These key features arguably constitute a fundamental shift in the global energy security paradigm from the one that emerged in the post 1970s era. Most importantly all of these features are interconnected and influence each other while simultaneously acting upon the global energy system as depicted in Figure 1-5. The scale of complexity and uncertainty now facing the global energy system is without
precedent in history with tremendous implications for how energy security is perceived. If a paradigm shift in the global energy system is occurring, this implies that current energy security policies and the long held norms of world governments may no longer be adequate or justified in the world today. This potentially has immense implications for how governments pursue both national security and foreign policy agendas in the pursuit of energy.

1.5 Hypothesis & Research Questions

The above analysis indicates that a central research problem in the energy security field is that current energy security policies are being challenged on multiple fronts and the substance of these challenges needs to be incorporated into a new concept of energy security (Von Hippel 2004). The following hypothesis is therefore posited:

The conventional energy security paradigm is no longer adequate for addressing the increasingly complex and interconnected challenges of the current global energy system. A new concept of energy security is therefore required which accounts for new and converging global priorities including climate change and sustainable development.

The hypothesis will be examined with the following research questions:

1. What are the driving forces behind the conventional energy security paradigm? How did the concept evolve and what implications does it have for energy security issues today and into the future?

2. What are the central features of a structural shift in the global energy security paradigm and what implications does this have for a new conceptualization of energy security?

3. What would a new energy security paradigm look like and how would it account for a new set of global priorities including climate change and sustainable development?

1.6 Structure of Analysis

The hypothesis and research questions are investigated as follows:

1. An evolutionary or historical analysis of the conventional energy security paradigm is conducted. This includes an overview of modern concepts of energy security, how they originated and evolved and how they affect policy actions today. This is used as baseline or reference point in assessing how the system is now changing.

2. Current changes in the global energy system are examined based on the following analytical framework: 1) shifts in energy demand and supply centres; 2) rising vulnerability and threat; 3) heightened geopolitical tension and, 4) converging global agendas.

3. A conceptual framework is presented to guide the development of energy security policies and strategies towards sustainability. Demand and supply-side energy security strategies along with geopolitical considerations are assessed from a sustainability perspective.

4. Reflections on the contribution of the sustainable energy security framework are provided followed by identification of research gaps for future study.
2 THE CONVENTIONAL ENERGY SECURITY PARADIGM: ROOT CAUSES & CURRENT IMPLICATIONS

2.1 Definitions

Energy security was a widely used term during the 1950s to mean safeguarding adequate energy supplies in the event of war. Although governments across the world define energy security differently, it typically means ensuring a reliable supply of energy resources at reasonable prices to support economic growth (Suzuki et al. 1998; Von Hippel 2004; Helm 2005; Dorian et al. 2006; Gupta & Jaswell 2006; UNECE 2006; Yergin 2006). Many existing definitions of energy security begin, and end with a focus on maintaining supplies of energy, particularly oil. Since the oil price shocks of the 1970s, energy security policy has focused on ensuring adequate supplies at reasonable prices without incurring supply disruptions. The concept has therefore moved beyond the traditional military aspect to include long-term economic safeguards against, *inter alia*, the effects of oil price volatility (Gupta & Jaswell 2006). Other contemporary definitions of energy security include:

1. “The objective of energy security is to assure adequate, reliable supplies of energy at reasonable prices and in ways that do not jeopardize major national values and objectives.”
   
   *Yergin*, 1988-

2. “The assurance that energy will be available in the quantities and qualities required under given economic conditions.”

   *World Energy Council*, 1992-

3. “A status of a society, which allows to maintain, in the context of internal and external threats and the influence of destabilising factors of economic, social, political, natural and technological origin, a required level of national security of the country by removing and setting off the adverse effects of these factors.”

   *Commonwealth of Independent States (CIS)*, 1996-

4. “The availability of a regular supply of energy at a reasonable price.”

   *International Energy Agency (IEA)*, 2001-

---


3 Proposed by state representatives in 1996 at an international advisory meeting on “Energy Security in the CIS” held May 1996 in Moscow at the initiative of the Security Council of the Russian Federation. A national expert from Tajikistan at the same conference suggested the following definition of energy security: “The provision of a state with energy carriers in a sufficient amount that allows keeping a necessary level of energy consumption in case of threats of an internal or external character and influence of destabilising factors of an economic, socio-political and technological origin” (UNECE 2001).
5. “The availability of usable energy supplies, at the point of final consumption, at economic price levels and in sufficient quantities and timeliness so that, given due regard to encouraging energy efficiency, the economic and social development of a country is not materially constrained”.

-United Nations Economic Commission for Europe (UNECE), 2006-

These definitions vary and are but a few among many possibilities. The common element among them is a central focus on reducing or mitigating the risk of energy supply disruption in the context of national economic and security interests.

### 2.2 Concepts

The Working Group on Asian Energy and Security at the Massachusetts Institute of Technology (MIT) Centre for International Studies defines the central goals of modern energy security as: 1) reducing vulnerability to foreign threats, 2) preventing a supply crisis and, 3) minimizing the economic and military impacts of a supply crisis. These goals assume that an oil supply crisis is the central focus for energy security policy. Oil has traditionally been the centrepiece for modern energy security policies because it is the dominant fuel in total primary energy supply for most developing and industrialized nations (Suzuki et al. 1998; EIA 2006; IEA 2006). Oil has also historically been the most strategic fuel for military purposes and is therefore directly linked to the economic and national security interests of a nation (O’Brien 1997). Table 2-1 summarizes the central concepts that underpin the modern energy security paradigm showing an overarching emphasis on oil supply security.

**Table 2-1. Summary of Conventional Energy Security Concepts**

<table>
<thead>
<tr>
<th>Goals</th>
<th>Risks</th>
<th>Strategies</th>
</tr>
</thead>
</table>
| ➤ Reduce vulnerability to foreign threats | ➤ Sudden oil supply disruption
➤ Sudden oil price shock<br>➤ Long-term oil resource depletion | ➤ Diplomatic relations (with oil exporting nations to prevent supply disruption)
➤ Reducing oil dependency through various means including conservation, efficiency, alternative sources (i.e. renewables, nuclear, natural gas, etc.)
➤ Strategic stockpiles
➤ Military intervention |

*Source: Adapted from Suzuki et al. 1998*

---

4 Considered the central risk to be protected from. Disruption can arise from a number of factors including extreme weather, politically motivated embargoes, military conflict, etc (Suzuki et. al 1998).

5 During the first two energy crises in 1973 and 1979, physical shortage of oil supply was less important than the price shock. Keeping oil prices stable is a central goal of conventional energy security policy. Price shock and sudden supply disruption is strongly correlated but not 100% (Suzuki et al. 1998).

6 Traditionally a major concern but subsided during the 1990s; has now re-emerged with intense debate about when oil peaking will occur (Suzuki et al. 1998; NETL 2007).

7 Considered one of the most effective ways to deal with a supply disruption crisis and/or price shock (Suzuki et al. 1998).
Both the military and economic foundations on which the modern energy security paradigm has been founded are reflected in the following key aspects of energy security recently proposed by the United Nations Economic Commission for Europe (UNECE 2006):

➤ Physical disruption of supplies due to infrastructure breakdown, natural disasters, social unrest, political action or acts of terrorism.

➤ Long-term physical availability of energy supplies to meet growing demand in the future.

➤ Deleterious effects on economic activity and peoples due to energy shortages, widely fluctuating prices or price shocks.

➤ Collateral damage from acts of terrorism resulting in human casualties, serious health consequences or extensive property damage.

In 1996, an international advisory meeting on Energy Security in the Commonwealth of Independent States (CIS) was held in Moscow at the initiative of the Security Council of the Russian Federation. During this meeting the heads of governments, corporate energy executives and leading scientists exchanged views on energy security in terms of domestic and international relations, different fuels and energy complexes, and major economic sectors. It was widely agreed that security of supply is the crucial factor to enhance energy security, and irrespective of whether a nation is a net importing or exporting country, secure energy supplies are critical for both economic and national security (UNECE 2001).

2.3 Policies

There are fundamental differences that shape a nation’s energy security policies. Various influencing factors include geopolitical alliances or rivalries, economic interests, technological considerations, distance to markets, national security interests, environmental and social goals, etc. (Suzuki et al. 1998; van der Linde et al. 2004). However, the following three overarching factors fundamentally influence the energy security position and policies a nation will take: 1) the level of domestic energy resource abundance or scarcity, 2) the level of government or market influence, and 3) whether a long-term or short-term perspective is taken. Importantly, these factors are inter-related and influence each other.

2.3.1 Access to Energy Resources

Countries that have abundant domestic energy resources typically have a greater set of energy security options than energy resource poor nations. In principle, energy rich countries are able to emphasize a global energy security perspective rather than national energy security – a position strongly taken by import dependent nations such as Japan, South Korea or France. This fundamentally influences the policies and strategies pursued between nations to enhance energy security. For example, the heavy dependence on imports has led Japan and France to pursue nuclear energy programs. Indeed, nuclear energy is considered a pillar of Japanese energy security policy. Strategies to reduce energy dependency arises from a heightened sense of vulnerability which is why energy security is tightly associated with national security. It can be viewed by energy poor countries that energy rich countries have the luxury to ignore what may be considered controversial strategies such as rapid nuclear power development. However, as energy markets become globalized a supply shortage or price spike can threaten all nations regardless of energy dependence or independence. This was made evident during the oil price shocks of the 1970s. National energy security has therefore been the dominant subject for energy security policy even for energy rich countries such as the United States attested by “Project Independence” initiated by the Nixon Administration immediately following the first oil crisis in 1973 (Suzuki et. al 1998).
Nevertheless, the level of domestic energy resources can have a strong influence on particular energy policies. For example, if a country is energy rich it can support local energy industry. If the industry is competitive than government intervention is not necessary but if it is not competitive than governments can assist through a variety of policy instruments such as subsidies or tariffs. The European Union (EU) for instance, possesses’ oil, gas and coal reserves but is far from self-sufficient and subsidizes the coal industry to maintain production and employment. Tariffs are also commonly used to shift demand away from imported energy towards domestic industry. Throughout the 1950s and 1960s European countries used trade policy to stimulate domestic refining rather than turning to more expensive imports. This bears upon energy exporting countries such as OPEC (Organization for Petroleum Exporting Countries) that see various fiscal policies and environmental restrictions as a barrier to international oil trade. For example, CO2 emission abatement policies in the EU are stimulating the expansion of renewables. Developing domestic resources can reduce energy dependency but can come at a high price (van der Linde et al. 2004). Governments will weigh the relative costs and benefits between investing into domestic supply against continued reliance on imports. It may well be that imports are more cost-effective in the short to medium-term rather than heavy capital investment into domestic resources with payback over the longer term. The level of domestic resources will shape energy security policies but is also influenced by whether a government takes a short-term or long-term perspective in terms of energy security and national interests.

2.3.2 Markets & Governments

Energy policies are also influenced by the degree to which market mechanisms or government dictates are used for energy resource transactions. If energy resources are viewed as commodities than market mechanisms are viewed to be the best way to allocate them. If energy resources are seen as strategic materials, this implies a direct role for governments. Indeed, the phrase energy “security” implies a central role for governments, which historically has been the case since energy security was linked to military interests. However, this changed with the commodity era of the 1980s and 1990s where energy was left to market forces (O’Brien 1997; Suzuki et al. 1998; Helm 2005). However, there are distinct differences in how market mechanisms or government controls are used for different energy resources. Should nuclear power technology and material for instance, be treated as commodities or strategic materials? The influence of markets and governments over energy is also affected by perspective and cultural norms. For example, the U.S. tends to view energy resources as commodities indicated by the deregulation of electric utilities, while Japan tends to view energy as strategic materials (Suzuki et al. 1998). Support for the U.S. nuclear industry is relatively low – although recently resurfacing as an option to enhance energy security. In contrast, nuclear power is a centrepiece of energy security policy in Japan. As discussed above, the level of support for certain energy options is greatly influenced by the level of energy dependency as a function of access to domestic resources. Tax policies also differ between market versus government approaches between Japan and the United States. Japan effectively used electricity and imported oil taxes to promote power siting, research and development and strategic oil stockpiles. When the U.S. tried to introduce an energy tax (a BTU tax) in the early 1990s it failed. The varying degrees of acceptance over taxes may reflect generic differences in attitudes toward the role of governments and markets between the two countries (Suzuki et al. 1998).

Whether markets or governments are preferred in energy resource transactions there will always likely be central role for governments in the case of energy security. For example, the development of nuclear power and the potential misuse of nuclear materials will always require some level of government intervention. And even if the market is preferred to allocate energy resources, well functioning markets require an appropriate policy framework. For all practical purposes it is difficult to separate markets and governments in the context of energy security. Therefore, the central debate boils down to perspective on whether energy should be viewed as a strategic material reflecting the pre-World War II to 1970s era or, as a commodity, reflecting the market liberalization agenda of the mid 1980s and 1990s (O’Brien 1997; Suzuki et al. 1998; Gupta & Jaswell 2006; Toichi 2006). Interestingly, with the globalization of energy markets, the need for both government intervention and well
functioning markets is becoming more important. For example, market integration is creating a highly complex global supply chain (LNG for example) underlining the need for governments to take an active role in protecting vulnerable supply chain routes. In this sense, the role of energy as a commodity and a strategic material is becoming more evident as the energy system globalizes.

## 2.3.3 Time Horizons

A third defining feature for energy security policies is whether a short-term or long-term view is taken (Suzuki et al. 1998). In terms of government policy, a short-term perspective may emphasize crisis management rather than long-term depletion of resources. Policies that focus on short-term gains may liquidate resources as opposed to stockpiling. A short-term perspective may therefore rely on the market to maximize returns as opposed to government policies to increase stability over the long-term.

For example, a longer-term energy-planning horizon may view the development of alternative fuels more competitively than a short-term energy security strategy that focuses on mitigating supply disruption. The time horizon that energy security policies take is therefore critical in determining what policy instruments are used, the level of reliance on market forces, or the overall level of government intervention.

What can be drawn from the above analysis is that along with physical resources and market forces, perceptions have a great deal of influence on how energy security policy is shaped. Despite key differences in energy security positions taken between nations, what can be concluded is that the modern energy security paradigm reflected in conventional definitions, concepts and policies is predominantly focused on security of supply — particularly oil supply — as a national security interest. The following traces the historical reasons for the preoccupation with oil supply and what implications this has for the world today.

## 2.4 Modern Roots

Although securing natural resources has been an integral part of society throughout history, energy did not emerge as a policy priority until the end of the 19th and early 20th centuries. The modern idea of energy security arose in the nineteenth century when warfare became mechanized requiring coal to fuel warships and trains. Before WWI, when the British Navy switched from coal-fired to oil-fired vessels the traditional link between petroleum and security began. Today, the terms energy security and oil supplies are implicitly linked. As a result, immense political, economic and military effort has been expended to secure fossil fuel supplies around the world (O’Brien 1997; Suzuki et al. 1998; Farrell et al. 2004). After WWII, the demand for petroleum products reached record highs by the 1960s due to economic rebuilding driven by large infrastructure construction. By the early 1970s, sustained levels of high petroleum demand over past decades reduced the surplus of crude reserves and refinery capacity. With gross demand levels reaching unprecedented heights in a relatively inefficient market the stage was set for the first oil supply crisis of the 1970s (O’Brien 1997).

In 1973, the OPEC oil embargo caused a major price shock as Arabian Light prices surged from 1.84\(^8\) USD/bbl (barrel\(^9\)) in 1972 to 10.77 USD/bbl in 1974. The other major price shock came during the Iranian revolution and the Iran-Iraq conflict when prices rose to an all-time high nearly reaching 40 USD/bbl (IEA 2005). By 1979, the Iranian Revolution interrupted 5 million barrels per day (mbd) of supply from Iran into world markets. A year later, war between Iran and Iraq further interrupted oil production. World oil markets reacted by driving oil prices to their highest levels in history. High oil prices were sustained by refiners, traders, and speculators and panicked consumers who built secondary and tertiary stock to unprecedented levels (O’Brien 1997). The OPEC embargoes and oil price shocks

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\(^{8}\) Prices are in 1970s U.S. dollars (USD).

\(^{9}\) Approximately 42 gallons.
The modern energy security system was created in response to the 1973 Arab oil embargo to ensure coordination among industrialized countries in the event of a supply disruption and deter politically motivated uses of oil by key exporters. The key elements of the modern energy security system include: 1) strategic stockpiles of oil, 2) monitoring of energy markets and 3) coordinated emergency sharing of supplies facilitated by the International Energy Agency (IEA 2004a). The emergency system was therefore established to respond to a potential disruption in oil supplies viewed as a direct threat to the global economy (Yergin 2007). Energy security policies to this day are remnants of the initial panic that followed the oil price shocks and supply disruptions of the 1970s, reflecting almost a singular focus on oil as a national security issue (WEF 2006). Despite the immense amount of political, economic and military resources invested into increasing “energy security” the concept itself is poorly defined and often viewed only as a problem of securing oil resources (Suzuki et al. 1998).

2.5 Oil Security & The Middle East

The modern energy security paradigm emerged in the wake of the oil price shocks of the 1970s, when industrialized nations converged upon the Middle East to secure oil in the interests of national security. The energy crisis of 1973 and the perceived threat that it posed to the industrialized world was one of the driving forces behind the first G7 meeting in Rambouillet France, 1975 (Kirton 2006). The G7’s principled statement of fact declared that world economic growth depended on energy availability (Kirton 2006). Reducing national vulnerability to the threat of supply disruption was therefore a central challenge the G7 was tasked with (Kirton 2006). Geopolitical manoeuvring was subsequently driven by the widespread belief that exogenous political events in the Middle East impacted the economies of industrialized nations through their effects on oil prices and supply disruptions (Barsky & Kilian 2004). As a result, securing access to oil and stabilizing the Middle East became both a national security concern and a foreign policy objective for oil dependent nations, most notably the United States.

Energy security policy has traditionally focused on Middle Eastern oil for the following key reasons: First, although the global market share of oil is expected to decrease over time (39% in 2003 to 33% in 2030) it will remain the world’s dominant fuel (Figure 2-1) (EIA 2006). Second, the Middle East holds the world’s largest oil reserves and is considered to be one of the most unstable regions in the world. Third, oil supply and prices can be influenced by political and military motives. Fourth, the global surplus crude production capacity was approximately one million barrels per day (mbd) or less, and surplus-refining capacity was equally limited (O’Brien 1997).

By maintaining stockpiles in the event of oil prices spikes, individual economies can moderate the effects and volatility of the market to some degree. The ability of an individual economy to mitigate the effects of higher oil prices depends on the size of their normal oil imports relative to the world oil trade. However, any form of stockpile draw down is a short-term response to oil price increases or supply shortages (McDonald et al. 2005).

The IEA was established by members of the Organization for Economic Cooperation and Development (OECD) during the 1973-74 oil crisis precipitated by the 1973 Arab-Israeli War and the oil embargo. The initial purpose of the IEA was to coordinate activities during oil supply emergencies. The 26 member countries of the IEA are Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and the United States. Poland and Slovakia have applied for IEA membership and the European Commission also participates in IEA activities. Notably, China, India and Russia are not currently part of the IEA system (WEF 2006).

U.S. Secretary of Defence, Henry Kissinger had identified the 1973 energy crisis as a “fundamental threat to both global economy and security” and a core reason for creating an annual G7 Summit (Kissinger 1975: 2 in Kirton 2006).
economy is vulnerable to oil price volatility particularly for oil dependent nations and key sectors such as transportation, petrochemicals and the military (Suzuki et al. 1998; World Bank 2002; Yergin 2006). Oil security has thus been a major concern for both oil importing and exporting economies since the first oil price shocks of the 1970s (McDonald et al. 2005).

![Figure 2-1. Fuel Shares of World Marketed Energy Use in 2003, 2015, 2030](image)

*Source: EIA 2006*

A key characteristic of the oil market is price volatility, defined as the standard deviation of monthly real oil prices (IMF 2005b; McDonald et al. 2005). Responding to this challenge has been central for conventional energy security policy. While there is widespread debate over the characteristics (i.e. magnitude and duration) of impacts resulting from oil price shocks, it is widely accepted that oil prices can affect the health of the economy (Awerbuch 2003; ADB 2005; IMF 2005; IEA 2006a). This norm is maintained because a negative relationship has been observed between oil price volatility and macroeconomic activity. For example, most post-World War II recessions in the U.S. were preceded by sharp increases in crude oil prices (Hamilton 1983 in Jones et al. 2004). Figure 2-2 shows percentage change in quarterly crude oil prices from 1947 to 2005 with vertically imposed shaded bars indicating the dates of subsequent recessions.

![Figure 2-2. Historical Trend Between Percentage Change in Quarterly Crude Oil Prices and US Recessions, 1947-2005](image)

*Source: Huo & Kliesen 2005*
A historical correlation appears to exist between oil price increases followed by recessions. Upon closer examination it was shown that over the period 1948-72 rising oil prices were followed 3-4 quarters later by slower economic growth (Hamilton 1983 in Awerbuch 2003). It was later confirmed that a 10% increase in oil prices led to GDP growth of approximately 0.6% lower than before the price increase (Hooker 1996 in Awerbuch 2003). A number of reasons have been put forward to explain this including oil price increases lead to higher production costs therefore lowering future GDP growth. Similarly, increased uncertainty about future oil prices may also affect aggregate output by delaying investment decisions or inducing sectoral resource reallocation (Huo & Kliesen 2005). In fact, oil market volatility has been held responsible for negative economic growth in the U.S. between 1999-2001 causing a 0.7% drop in GDP growth representing tens of billions of dollars in losses (Awerbuch 2003).

Traditionally, energy security policies have also focused on crude oil supply disruptions in the Middle East because of the observed correlation between Middle Eastern political events and oil price volatility. Although empirical analysis has both refuted and supported this argument, it is difficult to completely deny an association between the two (Barsky & Kilian 2004; Huo & Kliesen 2005). Figure 2-3 plots Middle East political events from the 1970s to 2005 and oil price volatility. Beginning in the 1970s market oil prices increased for a decade followed by a decline by the mid 1980s and by the end of the Cold War, the world saw a decade of cheap abundant oil (Deutch & Schlesinger 2006). This trend has reversed. By 2005, both real and nominal oil prices (West Texas Intermediate prices\textsuperscript{14}) reached their highest levels since the early 1990s. Although oil prices set new records in nominal terms, in real terms they have fluctuated between 20–40 USD/bbl remaining below the 1979 peak. Despite recent increases, the overall average trade weighted oil prices remain lower than the two previous oil crises during the early and late 1970s (ADB 2005; McDonald et al. 2005).

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\textsuperscript{14} West Texas Intermediate (WTI) is a light, sweet oil used for producing low sulphur fuels. Mainly used in the United States it is one of the most widely used benchmarks for oil prices. Brent crude is not as light or sweet as WTI, but still considered a high-grade crude oil mainly used in Europe. Crude oil is measured by two attributes: 1) viscosity (relative weight or API gravity) and 2) sulphur content. Oils that are more viscous are ‘heavy’, while less viscous oils are ‘light’. Light oil has an API greater than 35, medium is 26 to 35, and heavy is less than 26 API. Higher sulphur content (>5%) oil is ‘sour’ versus low sulphur content oil called ‘sweet’. High viscosity and sulphur content oil is more complex to refine incurring greater costs (McDonald et al. 2005; EIA 2006).
Martino Tran, IIEE, Lund University

The oil price shocks of the 1970s heightened the perceived vulnerabilities of oil importing nations to the interplay between oil prices, Middle Eastern politics and macroeconomic impacts. The modern energy security paradigm emerged as a response mechanism to the perceived threat that these factors posed for industrialized nations if one of them were to go out of balance. However, a much more central point was missed in that the energy security policies that arose during that time – with their central focus on securing oil supply – did little to reduce oil dependency therefore increasing the vulnerabilities that they were designed to mitigate.

The modern energy security paradigm is premised by the following two assumptions: First, oil price volatility is caused by political instability in the Middle East. Second, Middle Eastern political instability negatively impacts the economies of the industrialized world (Barsky & Kilian 2004; IEA 2004; ADB 2005; Guo & Kliesen 2005). As a result, modern energy security has come to mean stabilizing the Middle East through foreign policy or military intervention to reduce vulnerability to oil price shocks and supply disruption. These assumptions have motivated military intervention by industrialized nations into many of the world’s oil producing regions.

The underlying assumptions of the modern energy security paradigm can be challenged. First, oil price volatility cannot solely be attributed to Middle Eastern political events – there are a great many other factors involved, particularly in recent years as energy markets globalize. Second, empirical evidence directly linking negative macroeconomic effects upon industrialized nations to Middle Eastern instability and oil price shocks are not conclusive. Third, market mechanisms can mitigate the potential impacts of both supply disruptions and oil price shocks therefore challenging the argument that military intervention into oil producing regions is required to protect consumers in the developed world from oil price shocks (O’Brien 1997; Suzuki et al 1998; Gholz & Press 2007). These arguments are discussed below.

2.5.1 Oil Price Shocks

While oil price shocks have historically been linked to political instability in the Middle East and other major oil producing regions they are also influenced by a number of other interrelated factors discussed below.

2.5.1.1 Rising Demand

Oil prices reflect market demand and supply. Recently, demand for oil has reached all time highs largely do to strong economic growth in Asia, particularly China and India. Between 1990 and 2003, global oil demand grew at 1.3% compared to a combined 7% for China and India accounting for nearly 40% demand growth between 1990 and 2005. The combination of high-income elasticity\(^\text{15}\) for oil demand and relatively inefficient use of energy by these Asian giants increases pressure on an already tight oil supply market. Consequently, despite significant oil price increases, demand has remained strong in both countries. Oil demand has also been driven by strong growth in the U.S. and the rest of developing Asia\(^\text{16}\) reaching approximately 82 mbd in 2005 increasing by 1.3 mbd from 2004 (ADB 2005; IEA 2005; IMF 2005; McDonald et al. 2005).

\(^{15}\) Possibly 50% higher than the rest of the world (Verleger 2005 in ADB 2005).

\(^{16}\) In total, the increase in oil demand from developing Asian countries accounted for almost half of global demand expansion in 2004 (ADB 2005).
2.5.1.2 Inventory Levels
Shorter-run influences have also impacted prices. Due to capacity constraints, refiners have increased inventory levels. By mid 2005, OECD stocks increased to 54 days of forward consumption, compared to 51 days on average since 2002. Most countries have increased inventories in response to a tight and volatile oil market. In 2005, futures prices have typically exceeded spot prices, placing upward pressure on spot prices by reducing the cost of carrying inventories (ADB 2005).

2.5.1.3 Spare Production Capacity
Spare production capacity can act as a buffer in the event of a supply disruption. In recent years insufficient spare production capacity has driven oil prices up due to increased risk in the event of a supply disruption. In 2005, OPEC’s spare production capacity was 2.2 mbd but if regions prone to supply disruptions including Iraq, Nigeria and Venezuela are excluded spare production capacity drops to around 1.4 mbd (ADB 2005). Table 2-2 indicates that spare production capacity as a percentage of total capacity has dropped from 3.8% in 2002 to 1.6 – 2.2% in 2005. At about 2 million barrels per day spare production capacity was lower than any other time since 1991 (IMF 2005). Although the rate of global oil production capacity increased on average by 1.3% between 2002 and 2005, the rate of global demand almost doubled production capacity at 2.4% over the same period.

Table 2-2. Global Demand and Spare Production Capacity 2002-2005

<table>
<thead>
<tr>
<th>Global Totals</th>
<th>December</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2002</td>
</tr>
<tr>
<td>Capacity (mbd)</td>
<td>79.9</td>
</tr>
<tr>
<td>Demand (mbd)</td>
<td>76.9</td>
</tr>
<tr>
<td>Spare production capacity (mbd)</td>
<td>3.0</td>
</tr>
<tr>
<td>Spare production capacity as percentage of total capacity (%)</td>
<td>3.8</td>
</tr>
</tbody>
</table>

Source: IMF 2005a

The perceived higher risks associated with tight oil supplies are passed onto the market driving prices up (ADB 2005). Historically, high levels of spare production capacity has been linked to low real oil prices and low spare production capacity with high real oil prices shown in Figure 2-4 (IMF 2005b). Since 2002, spare production capacity has been declining and oil prices have risen. Furthermore, low spare production capacity has also been associated with high levels of price volatility shown in Figure 2-5. The historical trend shows that as spare production capacity falls, both real prices and volatility rise.
Low Investment

Inadequate investment throughout the 1980s and 1990s has impacted the current oil market. Limited spare oil production capacity partly results from low investment during the 1990s, due to low average real oil prices during that period (IMF 2005a). High exploration costs along with oil price volatility may have also contributed to poor investment into large projects (McDonald et al. 2005). Moreover, one of the central problems the industry is facing today is the mismatch between available crude oil supply and appropriate refining capacity (ADB 2005; IMF 2005). In past years, world oil demand has been driven by high-quality “light” and “sweet” crude oil. But recent additions to production capacity have been in the “heavy” and “sour” grades of crude. The lack of investment into appropriate refining capacity and limited substitution possibilities has driven retail prices up. Higher retail prices can also have the effect of lifting crude oil prices because the value of crude increases when the value of the
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final product increases (ADB 2005). Box 1 discusses the central implications of mismatching oil refineries with currently available supply.

Box 1. The Impact of Mismatching Refining Capacity on Oil Prices

1. Sour grades of oil are more costly and complex to refine into clean, low sulfur fuels than sweet grades. Upgrading refineries to refine sour oils is expensive and time consuming. Also, oil with higher sulfur content has increased health risks during the refining process causing higher overhead costs. Processing sour, heavy oil into sweet, light oils to meet market demand is also costly due to increasingly stringent regulations. The more stringent the regulations determining sulfur content and viscosity, the lower the yield of sweet light oil products per litre of heavy sour crude oil.

2. The demand for oil in many markets, particularly transport markets in developed economies, has increasingly been for light, sweet crude oils largely due to regulations mandating lower levels of sulfur in petrol and diesel fuels. This has placed pressure on already strained refining capacity. There have also been changes to regulations in Canada, Europe, Japan and the United States restricting the level of sulfur in fuels (Chernoff 2004 in McDonald et al. 2005). Stringent regulations will likely become more common as both industrialized and developing nations face increasing pressure from the international community to reduce the environmental and health impacts associated with oil consumption. This is particularly relevant for the booming economies of Asia that are highly dependent on oil for industrial and transportation end-use.

Investment in oil production, refining and distribution infrastructure stagnated during the low oil price period between the late 1980s and 1990s. With increasing demand, industry must now move from an exploitation phase into an investment phase. Higher oil prices in part reflect expectations for higher long-run marginal costs associated with an extended period of infrastructure investment. For example, future dated prices include a premium linked to financial risks associated with host country policies, rising equipment and labour costs and increasing project complexity (ADB 2005). Investment decisions to fund oil exploration, production and downstream industries are complicated by many uncertainties over oil prices, demand and lead time (2-8 years) for new capacities to be developed. Moreover, the experience of over investment following record high oil prices in the 1970s has increased the level of caution over investment decisions, which may delay new supplies coming on stream (ADB 2005; IMF 2005a).

Unpredictable real oil prices over the past two decades have also inhibited upstream investment. In the absence of detailed investment data, especially for OPEC members, investment is proxied by a measure of rig activity. Figure 2-6 shows the close association between real oil prices and global rig activity, which dropped in 1987 and has stagnated ever since. Unpredictability set against large price swings in the 1970s and 1980s has made it difficult to predict between transitory and permanent price changes and hence permanent cash flows. In the case of oil, given the large upfront outlays, long gestation periods and irreversible nature of investment, uncertain cash flows delay additions to productive capacity. Uncertainty regarding future prices is further compounded by difficulties in predicting long-term crude oil demand and its sensitivity to the rate of development and adoption of new technologies (IMF 2005).

17 For example, during July and August 2005, higher gasoline and diesel prices caused by refinery outages in the U.S. caused refineries still operating to bid up the price of light, sweet crude in order to profit from high retail prices (ADB 2005).

18 High cost over runs for Russia’s Sakhalin 2 liquefied natural gas project and Canada’s Athabasca oil sands project illustrate the risks associated with long-term investment planning and large complex projects (ADB 2005).
In general, a stringent global oil demand and supply balance combined with constraints along the entire supply chain due to a period of low investment have been key drivers behind high oil prices in recent years. The tight balance between demand and supply have two central implications for the modern energy security system: First, the ability of yesterday’s world oil markets to respond to supply interruptions has been weakened due to the disappearance of excess capacity compromising the major source of surge production in Saudi Arabia, and second, the system of emergency stocks held by IEA countries has been weakened by the emergence of non-member countries that have a significant impact on world oil markets, such as China and India (Giusti 2005).

Another major factor contributing to high oil prices is inadequate investment in refining capacity and other infrastructure in importing countries. Just as the lack of surge production capacity can prevent a rapid response to a crude oil supply disruption, stringent refining or transportation capacity can prevent a response to outages or rapid demand increases (Giusti 2005). The influence of perceived risks on oil prices is also important. In recent years, anxieties over Iran’s nuclear program, fears of terrorist attacks on Saudi Arabia and extreme weather events such as Hurricane Katrina have all driven oil prices up (ADB 2005; Yergin 2006).

What the analysis reveals is that a number of interrelated factors influence oil price volatility and therefore cannot be solely attributed to Middle Eastern politics. Without a doubt instability in the Middle East can lead to events that will negatively impact the oil market such as the OPEC oil embargo in 1973. And since the largest historical price shocks of the 1970s are associated with Middle Eastern events it is convenient to defer to Middle Eastern politics as the root cause for oil price volatility. However, continuing to draw this conclusion while excluding all other factors is a dangerous simplification of an increasingly complex and globalizing energy system.
2.5.2 Macroeconomic Impacts

The second central premise of the modern energy security paradigm is the assumption that exogenous political events in the Middle East impacts the economies of industrialized nations through their effects on oil prices. Two schools of thought have emerged on the relationship between energy prices and economic growth since the oil price shocks of 1973 and 1979. On the one hand, it is argued that high-energy prices lead to rapid reduction in economic growth. The counter-argument is that it is not higher energy prices but restricted money supply that have led to a slower pace of capital investment and technical change (Farrell et al. 2004). Although the relationship between oil prices and macroeconomic effects are the subject of much debate, Middle Eastern political events have nonetheless been held responsible for recessions, inflation, reduced productivity and lower economic growth in the industrialized world. The following examines empirical evidence to support these claims. The analysis draws heavily upon the work of Barsky & Kilian (2004) and does not aim to conclude that Middle Eastern oil events are not related to oil price shocks and macroeconomic effects. The intention is to demonstrate that the evidence for direct cause and effect is not conclusive. Caution therefore needs to be taken in developing policies based on assumptions that can lead to damaging conclusions and actions. This is especially important given the global implications that policies can have when giants such as the United States or China pursue energy security objectives.

2.5.2.1 Recessions

Middle Eastern political events have been held responsible for recessions in industrialized economies (Barsky & Kilian 2004). Table 2-3 lists the starting dates of recessions in the United States since 1972. Some of these recessions were preceded by Middle Eastern events that were followed by increased oil prices. As a result, a causal link is often made between Middle Eastern political events and recessions in the United States. In some cases recessions immediately follow Middle Eastern events such as the November 1973 recession immediately following the start of the war and oil embargo of the same year. On the other hand, the July 1990 recession preceded the August invasion of Kuwait by one month. And in other cases there were long delays between oil events and recessions. For instance, the March 2001 recession started two years after the OPEC meeting in March 1999. Similarly, there were one-year delays between the Iranian revolution in 1979 and a recession in 1980; and the Iran-Iraq war in 1980 followed by a recession in 1981 (Barsky & Kilian 2004). Based on this irregular pattern it is difficult to conclude that a direct correlation can be drawn between exogenous Middle Eastern political events and recessions in the U.S.

19 These two perspectives lead to different policy prescriptions. In the former analysis, it is advisable to keep energy prices steady. For the latter, it is advisable to have macroeconomic policies that minimize the impact of energy price fluctuations (Farrell et al. 2004).

20 The argument that oil has less of an effect upon the economy is the minority opinion among macroeconomists. Nevertheless, it is generally accepted that in recent years there is a weakening link between oil prices and economy for a number of possible reasons including increased energy efficiency in industrialized nations since the 1970s, stronger global economic growth and more efficient markets able to “weather” the impacts of oil price shocks (Clawson & Henderson 2005; IMF 2005; Klien et al. 2005).
Empirical evidence for a correlation between oil price increases and recessions is stronger than the link between Middle Eastern political events and recessions. Figure 2-7 plots the real price of oil since 1972 with business cycle peaks imposed as vertical lines. The data suggests that recessions in 1973, 1980 and 1990 are correlated with oil price increases. And although, the recessions in July 1981 and March 2001 occurred during oil price declines, they still occurred within months of a peak (Barsky & Kilian 2004). Due to a stronger correlation between oil price increases and recessions it could be implied that this supports a link between Middle Eastern political events and recessions. However, it is important to recall that oil price shocks can result from a variety of interrelated and complex factors that may or may not have to do with Middle Eastern politics (Section 2.5.1).
2.5.2.2 Productivity

There is also evidence to suggest a correlation between rising oil prices and declining productivity (Barsky & Kilian 2004; OECD 2004; ADB 2005). Table 2-4 gives comparative data relating the growth rate of total factor productivity (TFP)\(^{21}\) in the U.S. and the real price of oil within periods: 1950-1959, 1960-1973, 1974-1985, 1986-2001. The data reveals that the most significant drop in productivity occurred during the largest oil price shocks between 1974-1985.

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Real price of oil(^{22})</td>
<td>20.47</td>
<td>17.72</td>
<td>43.42</td>
<td>20.82</td>
</tr>
<tr>
<td>TFP(^{23}) (%)</td>
<td>1.99</td>
<td>1.18</td>
<td>0.31</td>
<td>1.34</td>
</tr>
</tbody>
</table>


2.5.2.3 Inflation

Middle Eastern events have also been held responsible for inflation (OECD 2004; Barsky & Kilian 2004; ADB 2005). Figure 2-8 shows the Consumer Price Index (CPI) inflation rates for the United States with the dates of key Middle Eastern events imposed as vertical lines. The data reveals that certain events including the invasion of Kuwait in 1990, the collapse of OPEC in 1986 and the OPEC meeting in 1999 were followed by sharp increases in CPI inflation. However, other events do not show a correlation. For instance, the Afghanistan war (2001) and Iraq war (2003) were both followed by a drop in consumer prices, while other conflicts such as the Iran-Iraq war had minimal impact on CPI inflation. Moreover, the largest spike in inflation in August 1973 began two months before the war broke out in October (Barsky & Kilian 2004).

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\(^{21}\) The neoclassical production function attributes economic growth to increases in the size of the labour force and to the amount of capital available, as well as to increases in “total factor productivity”. It is a catch-all for any part of growth that is not explained by labour and capital (IEA 2004).

\(^{22}\) USD in year 2000. (Oil price index deflated by US GDP deflator – measures the difference between real and nominal prices) (Barsky & Kilian 2004).

\(^{23}\) Annual multifactor productivity in the private manufacturing sector (Barsky & Kilian 2004). Multifactor Productivity (MFP) measures the changes in output per unit of combined inputs. Indexes of MFP are produced for private business, private nonfarm business, and manufacturing sectors of the economy (U.S. Dept. of Labour 2007) URL: http://www.bls.gov/mfp/
Although the overall pattern is irregular the strongest correlation between inflation and oil events is during the 1970s which saw a prolonged period of high inflation during a period where two of the most significant oil events occurred including the war of 1973 and the Iranian revolution in 1979. This association has led to the conclusion that oil price shocks arising from Middle Eastern oil events were responsible for economic stagnation and high inflation \(^{24}\) (Barsky & Kilian 2004).

2.5.2.4 Terms of Trade Effects

Another central macroeconomic impact that occurs from oil price increases is changes in purchasing power between oil-importing and oil-exporting nations called terms of trade effects. The extent to which oil-importing countries will suffer a reduction in purchasing power depends on the oil-intensity of production and the degree to which the demand for oil is price inelastic (OECD 2004; ADB 2005; IMF 2005a; EIA 2006). The impact on global demand depends on how much of the extra revenue accruing to oil exporters is respent (typically not fully respent in the short-term). Figure 2-9 shows terms of trade losses as percentage of GDP for OECD countries during the previous three oil price shocks. The graph reveals that terms-of-trade changes have been significant in the past but are moderate in the current episode, with some OECD economies improving including Canada, Mexico, Norway and Great Britain. One explanation for the moderate impacts during the 2003-04 period is that the global economy had stronger economic growth as compared to the 1979-80 period (IMF 2005). Although there appears to be a correlation the precise dynamics and magnitude of adjustments to the shift in the terms of trade are uncertain (IEA 2004).

\(^{24}\) Inflation can be influenced by the weight of oil products in the consumption basket. Secondary or indirect impacts are felt as producers pass higher oil costs to the price of final goods. Induced effects follow if higher goods prices lead to higher wage costs that feed back into prices (ADB 2005). For consumer price inflation, taxes on oil products can insulate the price level from oil price changes. Whether the increase in price level affects core inflation depends on the “second round” effects i.e. whether workers and enterprises are able to compensate for the income loss through higher wages and prices which, depends on the monetary policy regime in place (OECD 2004; ADB 2005).
Another way that oil prices can impact an economy is to cause a drop in consumption of energy using goods such as automobiles, which could then contribute to a recession (Hamilton 1996; Barsky and Kilian 2004). Related to the purchase of goods is the potential delay-effect in investment that an oil price surge may cause since consumers may postpone investments to determine if the price increase will be permanent (Bernanke 1983; Barsky & Kilian 2004). Figure 2-10 shows monthly automobile sales (million of units) in the United States. Oil events are imposed as vertical lines indicating periods of oil price increases and periods of investment uncertainty.

If investment uncertainty and purchases of energy using goods are channels that oil price shocks act upon the domestic economy, than a sharp drop in car sales is expected to occur after each oil event. This is not the case. Although there are declines in automobile sales after the shocks of 1974, 1979, 1990 they are gradual and represent a continuation of a declining trend that began before each oil event. In some cases, no significant change in car sale trends can be seen including 1980, 1999, 2001 and 2003 oil events. Also, after the collapse of OPEC in 1986 car sales on average increased (Barsky &
Kilian 2004). The evidence therefore casts doubt on at least one channel (i.e. domestic purchases of energy using goods) of how oil price shocks affects the domestic economy in relation to exogenous events in the Middle East.

Figure 2-11 uses a broader measure using monthly real consumption of durables in the U.S. showing similar results to automobile purchases. The data does not show a drop in consumption after oil price events in the Middle East. In fact, monthly purchases of durables generally increases between 1980 and 2003 with the only drop occurring in 1990 (Barsky & Kilian 2004).

![Figure 2-11. Middle East Events, Oil Price Uncertainty and Consumption of Real Durables in the U.S. 1971-2003](source)

Source: Department of Energy, Federal Reserve Economic Database and Bureau of Economic Analysis in Barsky & Kilian 2004

The same results hold true for investment decisions of firms during periods of oil price uncertainty associated with Middle East events. Figure 2-12 shows data for fixed non-residential investment and Figure 2-13 shows real investment in equipment and software.

![Figure 2-12. Middle East Events, Oil Price Uncertainty and Real Non-residential Fixed Investment in U.S. 1971-2003](source)

Source: Federal Reserve Economic Database in Barsky and Kilian 2004
The data does not support a link between Middle East events, oil price uncertainty and a drop in real fixed non-residential investment or real investment in equipment and software. On the contrary, investment trends in both cases rise.

2.5.2.6 Implications

The data presented above indicates that a definitive link between oil prices, Middle Eastern politics and negative macroeconomic impacts upon industrialized nations cannot be made. While the pathways in which oil prices can affect economic performance are generally understood, the precise dynamics and magnitude of these effects are uncertain. For example, quantitative estimates made by the IEA (2004) of overall macroeconomic damage caused by past oil price shocks on oil importing nations vary substantially (partially attributable to different methods used). And although, most of the major economic downturns in the United States, Europe and the Pacific since the 1970s have been preceded by sudden increases in the price of crude oil, other causal factors in some cases could have been more important (IEA 2004). For example, it has been questioned whether even large price shocks on a resource that accounts for 3-4% of GDP could cause the large GDP losses experienced in the U.S. and other industrialized nations. One explanation could be that recessions may be more attributable to post shock monetary policies rather than the oil shocks themselves (Bernanke et al. 1997; Jones et al. 2004; Sandalow 2006). Significantly, the oil price increases of 2005-2006 did not produce a recession. Possible reasons include better management of monetary policy and price shocks in recent years (2003-2004) have been less severe than in the 1970s. As a result, slower price increases have less of an impact because the economy is able to adjust (Hamilton 1996, 2003; Clawson & Henderson 2005; Sandalow 2006).

Moreover, empirical studies conducted since the late 1990s generally suggest that the link between the price of oil and the economy has weakened over time. One explanation is that energy efficiency has increased in industrialized nations. For example, energy intensity in the U.S. is half the level today as it was in the 1970s. Another reason put forward is that increased market efficiency allows the economy to absorb the impacts of oil shocks better now than in previous decades (IMF 2005; Klein et al. 2005). In fact, a strong case can be made for the increasing importance of markets in mitigating the impacts.

25 Although, the oil price spikes of the 1970s have often been blamed for the recessions that followed, this view has been challenged by Bernanke et al. (1997) claiming restrictive monetary polices played a larger role in those downturns (Sandalow 2006). Significantly, the oil price increases of 2005-2006 did not produce a recession. Possible reasons include sound management of monetary policy and a lower ratio of oil use to GDP than during prior price spikes (Sandalow 2006).
of oil shocks and supply disruptions.

2.5.3 Market Mitigation

The concept of energy security has evolved from a framework of military threats and diplomatic responses to include economic threats and market solutions. Energy markets have grown more efficient since the 1970s with market control widely dispersed among energy consumers, manufacturers, and suppliers. Although import dependency has increased in many industrialized nations, the ability to mitigate vulnerability to supply and price disruptions has changed substantially since the price shocks of the 1970s (Moore et al. 1997; O’Brien 1997).

Significant changes have occurred since 1980 in the way oil is traded making oil markets more efficient and potentially less volatile. First, traditional long-term contracts between producers and consumers have been replaced by spot markets where large volumes of oil are traded on a daily basis. The spot market has integrated the oil market onto an international level causing oil prices to be set according to changing world supply and demand conditions. Thus, regional imbalances in supply and demand are shifted quickly to an international level based on the strength of buying in various consuming markets. Second, the development of a futures market for oil and oil products has also reduced volatility and vulnerability of the oil market to large price shocks. Because prices are posted daily, the futures market adds valuable information for buyers and sellers about present and future market expectations. Importantly, futures contracts reduce the need to physically hold speculative inventory, thereby reducing the destabilizing role that inventory imbalances played in earlier periods of oil market instability (Moore et al. 1997).

Over the past 10–15 years technological, institutional and societal changes have favoured the liberalization of energy markets. It has become widely accepted that economic efficiency is promoted through decentralized energy markets with freely determined market prices. However, there continues to be a wide diversity of views among countries on the role of free markets in promoting energy security, which historically has been the responsibility of governments due to the strategic nature of energy supplies (Suzuki et al. 1998; UNECE 2006). Aside from this debate there is evidence that markets can play an important role in mitigating both supply disruptions and price shocks therefore challenging the historical role of governments to mitigate supply crisis.

2.5.3.1 Supply Recovery

A central aspect of modern energy security policies taken by the industrialized world and led by the U.S. is the use of military intervention to stabilize key oil-producing regions, particularly the Persian Gulf. A central argument behind the use of the military is to protect against the potential impacts upon consumers if energy supplies were to be disrupted due to political instability. However, in the five major oil supply disruptions associated with political events in the past 30 years, market dynamics mitigated the costs borne by consumers. The following tracks the decline and recovery of world oil production in five cases: 1) the Iranian oil industry strikes in 1978, 2) the collapse of the Iranian oil industry in 1979, 3) the start of the Iran-Iraq war in 1980, 4) the 1990 Iraqi invasion of Kuwait, and 5) the 2002–03 Venezuelan oil fields strikes. The data reveals that in four of the five cases (with the exception of the 1979 Iran disruption), major supply reductions in any country were quickly offset by production increases elsewhere (Gholz & Press 2007).

Figure 2-14 shows that the Iranian oil industry strikes in 1978 removed 5 mbd from global markets, which was more than 4% of world production at that time. Global production recovered in six months.
Figure 2-14. Iran 1978 and Global Oil Production


Figure 2-14 shows the Iran disruption in 1979. This is the exceptional case resulting in a significant drop in global oil production. At 9 months the disruption had removed more than 6% of global oil production.

Figure 2-15. Iran 1979 and Global Oil Production


Figure 2-15 shows the Iran disruption in 1979. This is the exceptional case resulting in a significant drop in global oil production. At 9 months the disruption had removed more than 6% of global oil production.

Figure 2-16 shows that the Iran-Iraq outbreak in 1980 removed 3.4 mbd of Iranian and Iraqi oil from global markets amounting to 5.8% of global production. Other producers increased their output within the same month offsetting 1.6% of the loss resulting in a net global supply drop to 4.2%. Losses to the world market were nearly replaced within three months and fully replaced in five months.
Figure 2-16. Iran-Iraq War 1980 and Global Oil Production


Figure 2-17 shows the first Gulf War in 1990 when Iraq’s invasion of Kuwait caused the most severe supply disruption. United Nations sanctions removed 5.3 mbd of Iraqi and Kuwaiti oil from world markets amounting to 8.8% of world production. Other producers increased output and within one month after the invasion, net world production was down by 5.9%, a month later 1.7% and in the following two months global production fully recovered.

Figure 2-17. Gulf War in 1990 and Global Oil Production


Figure 2-18 shows that Venezuelan production strikes in 2003 took only three months to replace the 2.3 mbd of disrupted oil production.
2.5.3.2 Price Recovery

Markets have also mitigated the effects of oil price shocks. In four of the five cases (with the same 1979 Iran exception) oil prices either remained nearly constant or quickly returned to predisruption levels. Figure 2-19 shows the price shock resulting from the 1978 Iranian oil strike followed by the collapse of the industry in 1979. Although the initial strike in 1978 had minimal impact on oil prices, which remained around 27-28 USD per barrel (in constant 2000 dollars) until the disruption was resolved, the industry collapse in 1979 caused a sustained increase in oil prices.

Figure 2-19. Iran Strikes and Industry Collapse 1978-1979 and Oil Prices

Source: Gholz & Press 2007

Figure 2-20 shows that the outbreak of the Iran-Iraq war in 1980 triggered an oil price increase of just over 20%, but returned to pre-war levels in 18 months. Furthermore, repeated attacks on shipping during the “tanker war” phase of the Iran-Iraq war had no discernible effect on global prices (Gholz & Press 2007).

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26 Prices reflect the refiner acquisition cost of oil and are quoted in 2000 U.S. dollars. Price changes are measured in Real terms (Gholz & Press 2007).
Figure 2-20. *Iran-Iraq War 1980 and Oil Prices*

*Source: Gholz & Press 2007*

Figure 2-21 shows the Gulf War in 1990 triggered a 100% price increase but recovered to pre-war levels within 8 months after the invasion of Kuwait.

Figure 2-21. *Gulf War 1990 and Oil Prices*

*Source: Gholz & Press 2007*

Figure 2-22 shows the Venezuelan oil strikes in 2002 – 2003 caused only a brief increase in oil prices and within five months prices returned to predisruption levels.
2.5.3.3 Implications

During the first Gulf war in 1991, both the private sector and government saw the importance of early and transparent information flow to avoid panic buying and logistical disruption. Dramatic oil price and supply shocks also did not occur during or after the Iraq war in 2003. Markets worked and oil supplies remained secure. Nevertheless, despite increased market efficiency, energy import dependence from a single region will remain a fundamental security supply risk (WEA 2004).

The other central implication for energy security policies is the causal link often made between oil price volatility, Middle Eastern politics and negative economic effects upon industrialized nations. The direct links between these factors is the subject of much debate and empirical analysis has supported a variety of interpretations (Hamilton 1996, 2003; Hooker 1996; Awerbuch 2003; Barsky & Kilian 2004; IEA 2004; Guo & Kliesen 2005). The above analysis demonstrates that in terms of drawing a direct line of cause and effect between Middle Eastern politics, oil price and supply disruptions and the impacts borne by consumers in the industrialized world, the evidence is far from conclusive. Furthermore, it has been shown that markets can mitigate the impacts of oil supply disruptions and price shocks. This calls into question the use of military force as a legitimate extension of energy security policies based on the premise of protecting consumers in the industrialized world. Despite evidence to the contrary, an immense amount of resources have gone into stabilizing the Middle East and other oil producing regions on the argument of reducing a foreign threat to western economies. These assumptions have led to military conflicts, which have exacted a devastating toll on populations and environment often in the name of energy security.
2.6 Implications of the Conventional Energy Security Paradigm

2.6.1 Oil Dependency

The most important implication of the conventional energy security paradigm is the excessive reliance on a single source of energy – oil. Compounding this problem is that most of the world’s oil is concentrated within a single region. As of 2005, world oil reserves were approximately one trillion barrels. Around 260 billion barrels are located in Saudi Arabia, by far the largest reserves in the world (Figure 2-23). The second, third, fourth and fifth largest reserves are also in the Persian Gulf region (Iraq, Iran, Kuwait and the United Arab Emirates) (Abbot et al. 2006). These countries combined have close to two-thirds of all the proved oil reserves in the world. Industrialised countries are becoming increasingly dependent on imported energy from this region. With the rapid industrialization of Asia and other developing regions, more people are competing for resources that will become concentrated in the hands of a few. With the rise of powers such as China, India and Russia there is a high potential for national interests to collide as nations compete for energy to fuel economic growth.

![Figure 2-23. World Proven Oil Reserves in 2004](image)

Source: BP 2004 in Abbot et al. 2006

Not only does global competition over a single energy resource concentrated within one region of the world have major implications from a geopolitical perspective, but also, oil dependency incurs a number of hidden costs. Most of the costs of producing, transporting, refining, and consuming oil are borne by the beneficiaries of oil use. However, these processes have side effects or external costs. External costs or externalities are defined as side effects of production or consumption activity that affect producers and consumers who are not part of the activity. Such costs are not considered by the generator, are not directly monetary, and imply a misallocation of society’s resources. Economic theory holds that the price of a commodity such as oil should reflect its marginal cost to society, where costs include economic resources used to produce and deliver the commodity plus costs to environmental resources, human health, and energy security etc. This market failure however, allows beneficiaries to not pay the full costs of oil in the prices of petroleum products purchased (Moore et al. 1997; Copolus 2003, 2007).
From a policy perspective, the ideal is to find a balance between the benefits of reduced harmful externalities and the costs of reducing the externality. In theory, the balance is found where incremental costs of avoidance are equal to the reduction in incremental external costs. At that point, damages to other activities have been internalized in the price of the externality causing activity, where additional expenditures to reduce remaining damages are not warranted on economic grounds. Estimating external costs is highly contentious due to conceptual and measurement problems and estimating the costs of avoidance is equally problematic. An approximation of the monetary value of various external costs can be made but typically leaves large areas for professional, public, and political disagreement. Generally however, the potential external costs associated with oil imports are placed into the following broad categories:

- The potential economic costs of less than fully competitive oil markets.
- The potential economic costs of large short term price shocks.
- The potential for other social costs such as environmental damages.

The important implication for energy security policies is that some portion of military expenditures for Middle East operations could be considered a cost of heavy dependence on oil imports (Moore et al. 1997).

### 2.6.2 The Cost of Energy Security

Since the 1970s energy security policy has involved military projection to “stabilize” or “democratize” key oil producing regions. The projection of military power in the gulf region for instance, is one of the central pillars of U.S. energy security policy (Clawson & Henderson 2005; Gholz & Press 2007). What warrants the extensive use of military intervention in the Middle East as opposed to other oil producing regions is that losses from other oil regions can be offset by surge production from the Gulf, but other regions could not in turn offset the loss of production in the Gulf. As a result, a supply disruption in the Middle East poses the unacceptable risk of paralyzing the economic and military forces of the industrialized world (Copolus 2003).

To illustrate the costs associated with conventional energy security policies the U.S. is examined because their energy security agenda impacts the rest of the world reflected in their military dominance. The U.S. also has a long-standing history of energy security policy in the Middle East summarized in Box 2.

**Box 2. Origin of US Energy Security Policy in the Middle East**

On February 14, 1945 an agreement was reached between President Roosevelt and King Ibn Saud where the U.S. would guarantee Saudi Arabia’s security in exchange for access to oil. From that time forward, every successive President, regardless of party would reaffirm that commitment. The mission to protect Middle East oil was first publicly recognized when President Carter created the Rapid Deployment Force in 1979 following the Iranian Hostage Crisis. In 1983, the mission to defend Middle East oil was made even more explicit when President Reagan created the U.S. Central Command and specifically included the defense of Middle East oil in its mission statement (Copolus 2003, 2007). Since 1980, every President has embraced the Carter Doctrine, declaring that “an attempt by any outside force to gain control of the Persian Gulf region will be regarded as an assault on the vital interests of the United States of America, and such an assault will be repelled by any means necessary, including military force” (Sandalow 2007).

---

27 The military dominance of the U.S. is without rival. While the UK and France have some global military capability, it is not on the same scale as the US. For instance, a single U.S. aircraft carrier battle group has a greater military capability than all the aircraft carriers of Britain and France combined (Abbot et al. 2006).
After the price shocks of 1973-74, the Pentagon prioritised the development of military forces in the Persian Gulf to secure oil supply and deny competitors control of the region (Kemp 2006). This strategy can be viewed as a “control” paradigm of security used to minimize threats to the military and economic dominance currently held by the U.S. as the world’s only superpower (Abbot et al. 2006; Kemp 2006; Pemberton & Korb 2007). The military capability of the US is unquestionable indicated by total military expenditures which is ten times higher than the United Kingdom (UK), the next largest military spender in 2005 (Figure 2-24).

![Figure 2-24. Top 10 Military Spenders in 2005](source: Stockholm International Peace Research Institute Yearbook 2006 in Pemberton & Korb 2007)

Energy security based on oil dependence comes at a high price. U.S. petroleum imports were $50.3 billion in 1998, $102.7 billion in 2002 and $179.2 billion in 2004 (EIA 2005 in Clawson & Henderson 2005). As previously discussed, the price paid at the pump is only a fraction of the real cost to the domestic economy. The consumer never sees the largest share of petroleum’s economic burden because it takes the form of externalities (costs that are not reflected in the price of a commodity) but is nonetheless real. Although there are a number of externalities related to oil import dependency the most significant with respect to energy security policy is the cost of oil-related defence expenditures (Copulous 2003, 2007).

The externalities of oil imports related to energy security polices are well recognized. These include maintaining a military presence to enhance the security of oil supply in unstable regions, protecting trade routes, maintaining strategic stockpiles (U.S. Strategic Petroleum Reserve) (Lieby et al. 1997; Lieby 2007) and engaging in direct military conflict (Copulous 2003, 2007). Perhaps the most significant is the U.S. protection of oil flow at key locations around the world providing incalculable benefits to global markets (Sandalow 2006). While these externalities are well recognized, quantifying them is a

28 The U.S. Control Paradigm of security can be characterized as 1) controlling access to fossil fuels, 2) maintaining global military supremacy, 3) protecting U.S. influence over international financial institutions, and 4) maintaining the military advantages held by regional allies. This approach to security is known as the ‘control paradigm’ because it seeks to keep threats to the status quo under control. Given the extent to which the US influences the international security agenda, the control paradigm will continue to define security and defence policies across much of the world (Kemp 2006).

29 Other key externalities related to oil import dependency include: loss of economic activity due to capital outflow, loss of domestic investment, loss of government revenue, and costs associated with oil supply disruptions (Copulous 2003, 2007).
difficult undertaking. For instance, attributing military costs to secure oil imports are contentious because a broader range of security and military objectives may be involved other than protecting energy supply.

In terms of cost-benefit analysis, the problem of “incrementality” also arises. For example, U.S. military activities undertaken for the purpose of protecting imported oil supplies may not be related to the actual volume of petroleum imports from the regions where they occur. Consequently, annual U.S. military expenses related to energy security activities may not vary in response to changes in the level of oil imports prompted by conservation efforts or other policies. Reductions in gasoline would therefore not likely result in identifiable savings in the military budget. However, this does not mean that military costs are not related to energy security policies, but that estimating the magnitude of incremental effects from changing oil use is problematic (Leiby et al. 1997; Leiby 2007).

Nevertheless, a comprehensive analysis of U.S. energy related defence expenditures has been conducted by the National Defence Council Foundation (2003). The analysis examined the entire United States armed forces along with a review of the Department of Defence budget to determine expenditures directly related to protecting oil supplies in the Persian Gulf region. Figure 2-24 provides a map showing the extent of military projection indicated by the sheer number of active military bases in the gulf region. Table 2-5 lists key U.S. military activities used as input into the analysis of energy security related expenditures.

![Figure 2-25. United States Military Presence in the Persian Gulf Region](image)
Circles on the above map represent U.S. military bases as of 2006 in the region. The majority of the bases are extensive and autonomous whereas others are stationed at a host country’s facility but consist of significant U.S. military presence. The U.S. also has a number of smaller facilities not shown on the map located in Iraq, Pakistan, Oman, Bahrain, United Arab Emirates, Qatar, Tajikistan and Afghanistan (Abbot et al. 2006).

Table 2-5. U.S. Military Activities Related to Energy Security in the Persian Gulf Region

<table>
<thead>
<tr>
<th>Event</th>
<th>U.S. Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iraq War (2003)</td>
<td>Launched where seizure and protection of Iraq’s oil fields was cited as a major objective.</td>
</tr>
</tbody>
</table>

Source: Copolus 2003

In October 2003 the National Defence Council Foundation released the results of a year-long review of oil-related defence costs entailing what the foundation claims to be the most comprehensive analysis of subject ever conducted. The analysis covered the entire order of battle of the United States armed forces down to the battalion or equivalent level, including an examination of roles and mission statements and unit histories. In addition, the entire Department of Defence budget was reviewed to determine if there had been any extraordinary expenditure directly related to protecting oil supplies. The analysis concluded that the fixed costs of defending Persian Gulf oil amounted to 49.1 billion USD annually. In 2006, the Foundation updated the 2003 estimate to include additional outlays that could be reasonably assigned to the protection of oil supplies since the start of Operation Iraqi Freedom and revised the figure to 137.8 billion USD per year (Table 2-6) (Copolus 2007).

Table 2-6. Military Costs Associated with Oil Supply Defence in the Persian Gulf (Billions)

<table>
<thead>
<tr>
<th>Event</th>
<th>US</th>
<th>Other nations</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Persian Gulf War (1990–1991)</td>
<td>6</td>
<td>53</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>61</td>
<td>53</td>
<td>2</td>
</tr>
<tr>
<td>Iraq War (2003–present)</td>
<td>US (2003 budget request)</td>
<td>74.4</td>
<td></td>
</tr>
<tr>
<td>2003 US fixed costs attributed to Persian Gulf oil supply security</td>
<td>49.1/yr.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006 US fixed costs attributed to Persian Gulf oil supply security</td>
<td>137.8/yr</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Copolus 2003, 2007

30 Remaining 2 billion dollars unidentified in NDCF (Copolus 2003) assessment.

31 Based on National Defence Council Foundation (Copolus 2003) study which accounted for pre-positioning equipment and materials in the Persian Gulf along with war-related costs which were arbitrarily allocated 50% towards oil security activities (albeit the allocation is based on comprehensive analysis of U.S. military expenditures related to operations in the Persian Gulf with the stated or observed purpose of oil supply security).

32 2006 updated estimates accounted for additional outlays that could reasonably be assigned to the protection of oil supplies (Copolus 2007).
The allocation of military expenditures towards the protection of oil supplies is problematic due to issues of attribution and incrementality. But the point is that the costs of modern energy security policies, using U.S. military expenditures as an approximation can be enormous. It is also important to note that the 137.8 billion/yr. figure is allocated towards direct expenditures for oil supply security. Bilmes and Stiglitz (2006) have estimated that the total economic cost of the Iraq War alone, to be in the trillions (Table 2-7).

Table 2-7. Total Economic Costs of the Iraq War (Billions) as of 2006

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>USD (Billions)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Budgetary Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Spending to July 2006</td>
<td>336</td>
</tr>
<tr>
<td>Future operating costs*</td>
<td>389</td>
</tr>
<tr>
<td>Veterans health care and disability compensation*</td>
<td>127</td>
</tr>
<tr>
<td>Net increased defence and demobilization costs*</td>
<td>160</td>
</tr>
<tr>
<td><strong>Economic Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Net economic adjustments (loss of life, brain/spinal/other injuries, reserve pay, net of disability pay)</td>
<td>355</td>
</tr>
<tr>
<td>Oil price transfer (supply-side) effect</td>
<td>300</td>
</tr>
<tr>
<td>Oil aggregate demand effect</td>
<td>150</td>
</tr>
<tr>
<td>Budgetary impact</td>
<td>450</td>
</tr>
<tr>
<td><strong>Total Costs of the War</strong> (without interest)</td>
<td>2267</td>
</tr>
</tbody>
</table>

*Net present value of future expenditures

Source: Bilmes & Stiglitz 2006

Before the war, commodity futures markets forecasted oil prices would remain in the 20 – 30 USD/bbl range in spite of strong economic growth in China and India. Today, futures markets predict oil prices will be in the mid 60 USD/bbl range throughout 2007 and 2008. One explanation is that instability in the Middle East due to the Iraq war has increased the risk of investing in the region. And since costs of extraction are so much lower in the Middle East, high oil prices have not stimulated a commensurate supply response elsewhere. Of the 45 USD/bbl increase since the war began a conservative calculation was made based on the assumption that 5 to 10 USD is due to Iraq. Since U.S. imports are around five billion barrels a year a 10 USD/bbl increase translates into an extra expenditure of approximately 50 billion USD. If a 5 USD price increase is sustained for five years, this translates into 125 billion USD in costs. If the estimate is based on a 10 USD price increase for at least six years the cost is 300 billion USD. In addition to the direct supply-side costs, higher oil prices may reduce domestic expenditures causing a reduction in aggregate demand leading to lower economic output. Therefore, assuming the economy remains below its potential an “oil multiplier” of 1.5 (over 2 years) was used resulting in a cost estimate of 450 billion USD (Bilmes & Stiglitz 2006).

The costs listed above are enormous because the potential macroeconomic effects arising from higher oil prices following the war are accounted for. The irony is that although the central objectives of conventional energy security policy are to minimize macroeconomic impacts, stabilize the Middle East and avoid high oil prices – the military intervention into Iraq if considered to be part of U.S. energy security policy achieved exactly what it is supposed to avoid. This claim would be precluded if in fact
U.S. intervention into Iraq was not part of a broader energy security strategy, but for all of the other reasons given including the ejection of a tyrant, the liberation of the Iraqi people, the establishment of democracy and the elimination of weapons of mass destruction – the existence of which has not yet been substantiated by any concrete evidence. If indeed, all of these reasons hold true than the next question is, if Iraq and the Middle East did not by far have the world’s largest oil reserves on the planet would all the other reasons be enough for the U.S. to intervene with force? This is not a judgement or even a critique of the United States, but an observation of the contradictory and conflicting nature of modern energy security policies based on oil dependency.

2.6.3 Vulnerability in Developing Nations

One of the central implications of a modern energy security paradigm fixated on oil is the disproportionate impact of high oil prices on low income developing nations. Sustained economic growth worldwide and reduced spare production capacity have led to a precarious balance between supply and demand placing upward pressure on oil prices in recent years (Figure 2.25) (Bacon & Kojima 2006). Between 2003 and 2006, world oil prices rose from 25 USD/bbl to more than 78 USD/bbl. For several African countries, increased oil costs during this period substantially exceeded savings through debt relief (Sandaw 2006). The impact of oil prices upon developing countries depends on the degree of oil self sufficiency, the level to which an economy depends on oil as a primary fuel and the energy intensity of an economy (Bacon 2005).

![Figure 2.26. Recent Oil Price Increases 2000 – 2006](source: Bacon & Kojima 2006)

The adverse economic impacts of higher oil prices on oil-importing developing countries are generally more severe than for OECD countries. This is because their economies are more dependent on imported oil and are more energy-intensive. Oil-importing developing countries typically use more than twice as much oil to produce a unit of economic output than OECD countries (IEA 2004; ADB 2005; Bacon & Mattar 2005; IMF 2005c; EIA 2006). Figure 2-26 shows global oil intensity has decreased over time since the 1970s, but the oil intensity among non-OECD countries remains almost twice that of OECD countries suggesting a higher degree of vulnerability to oil price shocks (oil intensity is measured as thousands of tons of oil consumed per billion U.S. dollars of real GDP 1995 terms)
From a macroeconomic perspective, the vulnerability of an oil importing country is measured by the ratio of the value of net oil imports to GDP – the higher this ratio the larger the decline in GDP required to offset a rise in oil prices. The impact of the oil price shock is calculated as the index of vulnerability multiplied by the percentage increase in oil prices. Oil vulnerability is equal to the product of four factors shown below (Bacon & Mattar 2005; IMF 2005c):

\[
\text{Oil vulnerability} = \frac{\text{value of net oil imports}}{\text{GDP}} = \text{Price of oil} \times \left( \frac{\text{volume net oil imports}}{\text{total oil use}} \right) \times \left( \frac{\text{total oil use}}{\text{total energy use}} \right) \times \left( \frac{\text{total energy use}}{\text{GDP}} \right)
\]

Net oil imports/total oil use = 1 – self sufficiency in oil production

Total oil use/total energy use = dependence on oil as energy source

Total energy use/GDP = energy intensity

Oil intensity = oil use/GDP = oil dependence x energy intensity

The vulnerability to oil price change is shown in Table 2-8 for five regions of the world excluding net oil exporters whose economies respond differently to higher oil prices.

Table 2-8 shows that the developing nations in East Asia in 1990 and 2003 are around four times more vulnerable to oil price shocks than OECD countries. Across all regions, Sub Saharan Africa and East Asia are the most vulnerable because of an almost complete dependence on energy imports along with a high dependence on oil for primary energy supply. East Asia’s vulnerability slightly exceeds that of Sub Saharan Africa, but Africa by far has the highest debt/GDP ratio and the lowest GDP per capita suggesting a lower ability to cope with an oil shock.

It may appear that the high-energy intensity of South Asia should increase the level of vulnerability but this is offset by the lowest oil dependency across all regions. OECD countries on the other hand, have a relatively high import dependency but have exceedingly low energy intensities, lower even than Sub Saharan Africa in 2005. This is consistent with historical trends that show a decoupling between
primary energy consumption and GDP growth after a certain level of affluence is reached, which may be explained by a transition from energy intensive industrial growth towards low intensity service, information and knowledge economies33 (Goldemberg 1997). This trend may have important implications for Africa if GDP continues to rise, energy consumption may also rise before peaking and falling resulting in higher levels of vulnerability at least in the short to medium term (Bacon & Mattar 2005).

Table 2-8 also indicates that East Asia was highly vulnerable to oil prices in 1990, being almost entirely dependent on imported oil yet managed to grow substantially between 1990 and 2003. This suggests that there are ways to offset high-energy import bills without depressing overall economic growth. The mechanism to explain this is not well-understood requiring further investigation (Bacon & Mattar 2005).

33 The delinking of energy consumption and GDP growth occurs because: 1) consumer goods markets become saturated in industrialized societies where economic activity shifts towards services away from heavy industry; 2) a shift towards using less energy-intensive materials; 3) a shift from traditional, inefficient non-commercial fuels to modern energy sources including electricity, liquid and gaseous fuels, and processed solid fuels; 4) the adoption of new and more energy-efficient technologies (Goldemberg 1997).
### Table 2-8. Oil Vulnerability for Non-Oil Exporting Developing Countries and OECD 1990 and 2003

<table>
<thead>
<tr>
<th></th>
<th>Sub-Saharan Africa</th>
<th>Latin America &amp; Caribbean</th>
<th>South Asia</th>
<th>East Asia</th>
<th>OECD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1990</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vulnerability</td>
<td>0.0273</td>
<td>0.0193</td>
<td>0.0161</td>
<td>0.039</td>
<td>0.0143</td>
</tr>
<tr>
<td>Oil price (USD)</td>
<td>23.7</td>
<td>23.7</td>
<td>23.7</td>
<td>23.7</td>
<td>23.7</td>
</tr>
<tr>
<td>Import dependency</td>
<td>0.985</td>
<td>0.619</td>
<td>0.506</td>
<td>0.927</td>
<td>0.705</td>
</tr>
<tr>
<td>Energy intensity</td>
<td>10154</td>
<td>13697</td>
<td>24013</td>
<td>15204</td>
<td>11122</td>
</tr>
<tr>
<td>Oil dependency</td>
<td>0.665</td>
<td>0.543</td>
<td>0.320</td>
<td>0.680</td>
<td>0.425</td>
</tr>
<tr>
<td>TPEC per capita</td>
<td>3.3</td>
<td>33.1</td>
<td>9.0</td>
<td>15.4</td>
<td>203.6</td>
</tr>
<tr>
<td>Debt/GDP</td>
<td>0.829</td>
<td>0.365</td>
<td>0.312</td>
<td>0.471</td>
<td>NA</td>
</tr>
<tr>
<td>GDP per capita (USD)</td>
<td>261</td>
<td>2648</td>
<td>327</td>
<td>1130</td>
<td>20581</td>
</tr>
<tr>
<td><strong>2003</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vulnerability</td>
<td>0.0351</td>
<td>0.0206</td>
<td>0.0292</td>
<td>0.045</td>
<td>0.0105</td>
</tr>
<tr>
<td>Oil price (USD)</td>
<td>28.8</td>
<td>28.8</td>
<td>28.8</td>
<td>28.8</td>
<td>28.8</td>
</tr>
<tr>
<td>Import dependency</td>
<td>0.982</td>
<td>0.478</td>
<td>0.744</td>
<td>0.852</td>
<td>0.695</td>
</tr>
<tr>
<td>Energy intensity</td>
<td>11421</td>
<td>16507</td>
<td>22150</td>
<td>19187</td>
<td>6819</td>
</tr>
<tr>
<td>Oil dependency</td>
<td>0.626</td>
<td>0.510</td>
<td>0.352</td>
<td>0.530</td>
<td>0.421</td>
</tr>
<tr>
<td>TPEC per capita</td>
<td>3.8</td>
<td>42.8</td>
<td>12.1</td>
<td>27.1</td>
<td>225.3</td>
</tr>
<tr>
<td>Debt/GDP</td>
<td>0.723</td>
<td>0.504</td>
<td>0.240</td>
<td>0.520</td>
<td>NA</td>
</tr>
<tr>
<td>GDP per capita (USD)</td>
<td>294</td>
<td>3056</td>
<td>504</td>
<td>1527</td>
<td>25414</td>
</tr>
<tr>
<td><strong>% Change</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vulnerability</td>
<td>+28.8</td>
<td>+6.3</td>
<td>+82.0</td>
<td>+13.7</td>
<td>-26.7</td>
</tr>
<tr>
<td>Oil price</td>
<td>+21.5</td>
<td>+21.5</td>
<td>+21.5</td>
<td>+21.5</td>
<td>+21.5</td>
</tr>
<tr>
<td>Import dependency</td>
<td>-0.3</td>
<td>-22.8</td>
<td>+47.1</td>
<td>-8.0</td>
<td>-1.4</td>
</tr>
<tr>
<td>Energy intensity</td>
<td>+12.5</td>
<td>+20.5</td>
<td>-7.8</td>
<td>+26.2</td>
<td>-38.7</td>
</tr>
<tr>
<td>Oil dependency</td>
<td>-5.8</td>
<td>-6.1</td>
<td>+10.4</td>
<td>-21.1</td>
<td>-0.8</td>
</tr>
<tr>
<td>TPEC per capita</td>
<td>+5.4</td>
<td>+29.1</td>
<td>+34.3</td>
<td>+76.5</td>
<td>+10.7</td>
</tr>
<tr>
<td>Debt/GDP</td>
<td>-12.8</td>
<td>+38.0</td>
<td>-23.0</td>
<td>+10.8</td>
<td>NA</td>
</tr>
<tr>
<td>GDP per capita (USD)</td>
<td>+12.7</td>
<td>+15.4</td>
<td>+54.0</td>
<td>+35.1</td>
<td>+23.5</td>
</tr>
</tbody>
</table>

Source: Bacon & Mattar 2005

---

34 Table 2-8 Notes:
1. Oil vulnerability is defined as the value of net oil imports divided by current GDP calculated from data on oil production and oil product consumption (in 000 barrels a day) from EIA (2005) database. Values are estimated by multiplying volumes by the Brent price of oil for that year. The measure is dimensionless.
2. The oil price is for dated Brent blend averaged for the year taken from Platts Oilgram Price Report. Units are USD per barrel of oil. Different regions and countries pay different amounts per barrel for oil and oil products, but the general price increase over the period will be very similar for all regions.
3. Import dependency is the difference between oil consumption and oil production divided by oil consumption, using the same data as for vulnerability. The measure is dimensionless.
4. Energy intensity is measured by the ratio of total primary energy consumption (in quadrillion BTU) divided by GDP in 2005 USD billion. Total primary energy consumption (which is measured net of biomass) is taken from the IEA 2005 database. GDP data is from the World Bank Central database in BTU per USD.
5. Oil dependency is the ratio of consumption of oil in BTU to total consumption of primary energy in BTU. Data is from EIA 2005 database. The measure is dimensionless. The standard conversion factor for 1 barrel of oil is 5.8 million BTU. Oil products, especially gasoline, have lower conversion factors.
6. Sub-Saharan Africa excludes South Africa, since its dominant size weights the aggregate picture very heavily.
7. East Asia omits China, since its history of economic development and size distort the picture for the region and affect inter-regional comparisons.
8. Only developing countries are included in the regional aggregates, all net oil (crude and products) exporting countries are excluded.
9. GDP per capita in current 2005 USD is from the World Bank Central Database.
10. The ratio of external debt to GDP (both in 2005 USD) is from the World Bank Central Database (Bacon & Mattar 2005).
The impact of an oil shock upon a country is proportional to the percentage increase in oil prices multiplied by the ratio of net imports of oil and oil products to GDP. Table 2-9 shows the impacts upon GDP of a sustained 10 USD increase from 23 USD/bbl. Results are shown for 131 countries grouped by per capita income levels.

Table 2-9. Percentage Change in GDP for a 10 USD a Barrel Increase in Oil Prices for Net Oil Importers

<table>
<thead>
<tr>
<th>Per Capita Income (1999-2001 USD)</th>
<th>% Change in GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;300 (18 countries)</td>
<td>-1.47</td>
</tr>
<tr>
<td>&gt;300 and &lt;900 (36)</td>
<td>-0.56</td>
</tr>
<tr>
<td>&gt;900 and &lt;9000 (36)</td>
<td>-0.56</td>
</tr>
<tr>
<td>&gt;9000 (21)</td>
<td>-0.44</td>
</tr>
</tbody>
</table>

Source: Adapted from Bacon 2005

The results indicate that the loss of GDP for countries with a per capita income less than 300 USD is more than three times the loss experienced by countries with a per capita income greater than 9000 USD. Poorer countries are more vulnerable to oil price increases because of higher oil dependency but also, low per capita income can exacerbate impacts at the household and firm level. For example, households can be affected directly through purchases of kerosene, LPG and gasoline and indirectly through transportation costs and other costs passed on to market goods (e.g., higher transport fuel costs will raise the costs of processed goods). The impact of higher energy prices on household expenditures can disproportionately increase the cost of living for the poor. This arises from low purchasing power coupled with low price elasticity’s of demand for energy services in the short run (Bacon 2005). The increased cost of living for the poor is consistent with low-income households typically spending a greater share of total income to obtain energy services as compared to higher income households35 (Takeda 2000).

2.6.4 Climate Change

Another direct implication of an oil-based economy is climate change36. Currently, 80% of worldwide energy use is based on fossil fuels with the total share projected to increase. Fossil fuel combustion releases emissions into the environment causing climatic changes, air pollution and human disease. The effects of emissions can be local (e.g. grit, benzene or soot), regional (e.g. aerosols, short-lived gases) or global (persistent greenhouse gases). Emissions of persistent greenhouse gases – carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) have significantly contributed to a 0.6°C increase in the mean ground-level air temperature over the past 100 years. The Intergovernmental Panel on Climate Change (IPCC) forecasts a rise in mean temperature between 1.4 and 5.8°C over the next 100 years depending on human behaviour. The IPCC considers a mean global temperature change of more than 2°C

35 The poor typically spend a greater fraction of income on indispensable energy services, such as cooking, than do the rich. Also they frequently forgo services like lighting and space heating that require energy carriers (e.g., electricity) and devices (e.g., fluorescent lights) to which they either don’t have access, or cannot afford. In general, people in poverty expend more time and effort to obtain energy services of lower quality than the energy services available to the rich (Takeda 2000).

36 The risk of irreversible ecosystem damage is related to the level and rate of global warming. Fossil fuel combustion generates benzene (C₆H₆) and soot emissions which damages human health and ecosystems; nitrogen oxides (NOₓ), hydrocarbons and carbon monoxide (CO) are also released increasing ground-level ozone which reduces the self-purifying capacity of the atmosphere; nitrogen and sulphur oxides (SOₓ) as well as ammonia are converted chemically in the atmosphere and enter soils through acid deposition. The current global energy system damages the natural environment and jeopardizes human health (WBGU 2004).
relative to preindustrial levels intolerable. If this upper bound limit is exceeded the predicted shift in climatic regions combined with weather extremes including floods and drought could severely impair the natural basis of existence for millions of people, particularly for the most poor in developing nations. The concentration of CO$_2$ in the atmosphere is currently 378 ppm and increasing at 1.5 ppm per year. If the concentration of CO$_2$ in the atmosphere exceeds 400 parts per million (ppm), there is a chance of exceeding the upper bound limit of 2°C. This leaves 14 years before the 400 ppm point is reached. The World Health Organization (WHO 2004) already attributes at least 150000 deaths per year to the early effects of global warming. The highest proportion of these deaths are in Southern Africa one of the poorest regions in the world (Figure 4-2) (IPCC 2001; WBGU 2004; WEA 2004; Abbot et al. 2006).

![Figure 2-28. Mortalities Attributed to Climate Change](source: World Health Organization 2004 in Abbott et al. 2006)

Table 2-10 below illustrates examples of global impacts projected for climate changes (along with sea-level and atmospheric carbon dioxide where relevant) associated with different increases in global average surface temperature in the 21st century. The black lines link impacts; dotted arrows indicate impacts continuing with increasing temperature. All entries are placed so that the left hand side of text indicates approximate onset of a given impact. Confidence levels for all projected impacts are considered high by the Intergovernmental Panel on Climate Change (IPCC) explained in detail in the IPCC Fourth Assessment Report (IPCC 2007). Although the described impacts will vary by extent of adaptation, rate of temperature change and socio-economic pathways, impacts nonetheless are expected to affect water systems, ecosystems, food availability, heavily populated coastal areas with direct and indirect impacts upon global human health. What these projections indicate is that climate change poses a common threat to the world, with the most immediate and severe impacts affecting vulnerable populations in developing nations (IPCC 2007).
Climate change is one of the most important challenges with profound implications for international security and human well-being. An energy security system based on fossil fuel dependency is already the cause of sustained human conflict. This combined with the direct contribution to climate change is the imperative for a fundamental shift away from fossil fuel dependency towards a sustainable energy system. The energy security paradigm must evolve to engender the development of energy security policies that respond to these challenges rather than perpetuate them.
3 TRACING THE STRUCTURAL SHIFTS OF THE MODERN ENERGY SECURITY PARADIGM

The modern energy security paradigm emerged in the wake of the 1970s energy crises. At that time, the primary focus for Western industrialized countries was on oil supply sources and geopolitics. These two elements were the underlying causes of energy security concerns. Over the past 30 years, the characteristics of traditional energy security elements including supply sources demand centres, geopolitics and markets have changed, and new elements have emerged (WEF 2006; Yergin 2006). These changes constitute what proponents are calling a shift in the modern energy security paradigm (O’Brien 1997; Suzuki et al. 1998; Von Hidden 2004; Helm 2005; JFIR 2006; Toichi 2006; WEF 2006; Yergin 2006, 2007). This potentially has significant implications for how governments conceive, formulate and deploy energy security policies in the 21st century. The following assesses the key features that constitute a paradigm shift in the modern energy security system and what implications this has for a new conceptualization of energy security. These key features are categorized and assessed as follows: 1) structural shifts in demand and supply, 2) rising vulnerability and threat, 3) heightened geopolitical tension and 4) converging global agendas.

3.1 Structural Shifts in Demand & Supply

A fundamental shift is occurring in the demand-supply structure of the global energy system with demand centres shifting away from OECD countries towards developing nations. Similarly, supply production is becoming more concentrated in non-OECD Middle East and North Africa (MENA) countries. Rising energy demand, declining production capacity, inadequate investment and the fear of oil peaking are placing severe stress on the energy system unseen in previous decades.

3.1.1 Shifting Demand Centres

By 2030, global energy demand is projected to increase more than 50% from current levels at an average annual growth rate of 1.6% for at least 25 years (Figure 3-1) (Birol 2006). Oil, coal and gas will account for more than 90% of the projected increase in demand. Oil is expected to remain the single largest fuel source with two-thirds of the increase arising from the transport and industrial sectors (IEA 2005; EIA 2006). Increasing global prices could reduce oil’s share in the world energy market as other fuels replace oil where possible (EIA 2006). Coal use will remain concentrated in China, India and other Asian economies due to abundant reserves and cost effective production. Natural gas is expected to be the fastest-growing fuel, estimated to double in volume between 2000 and 2030. Natural gas demand is driven mainly by power generation overtaking coal as the world’s second-largest primary energy source by 201537 (IEA 2005; Birol 2006; Dorian et al. 2006). Natural gas will play an important role in terms of regional geopolitics as the European Union becomes increasingly dependent on Russian gas reserves along with U.S. integration into the global gas market. Although, higher fossil fuel prices may support renewed interest in nuclear power total market share for nuclear is expected to marginally decline, while hydropower remains constant (IEA 2005; EIA 2006). The share of non-hydro renewables, including biomass, geothermal, solar, wind, tidal and wave energy are also expected to remain constant (Birol 2006). However, renewable energy may increasingly contribute to electricity generation with wind and biomass expanding from a small base (Dorian et al. 2006).

37 For comparative purposes, the EIA (2006) projects that higher gas prices makes coal more cost competitive. As a result, demand for coal grows faster than demand for natural gas albeit only slightly faster at 2.5% per year. Among the end-use sectors, the industrial sector remains the largest consumer of natural gas worldwide, accounting for 52% of the total increase in demand between 2003 and 2030. Natural gas is also expected to remain an important energy source in the electric power sector, particularly for new generating capacity (EIA 2006).
Between 2002 and 2030, a fundamental structural shift is expected to occur as global demand for energy shifts away from OECD nations towards developing countries. Figure 3-2 shows that between 2002 and 2030, two-thirds of the increase in world primary energy demand will arise from developing countries with OECD countries accounting for 26% and transition economies 8%. As a result, the current share of the OECD in world demand will decline from 52% in 2002 to 43% in 2030, while developing countries will increase from 38% to 48% with transition economies falling from 10% to 9% (IEA 2004).

The key driver for rapid increase in energy demand from non-OECD regions is strong economic growth. For all non-OECD regions combined, economic activity (measured by GDP in purchasing power parity) is expected to expand on average by 5% per year as compared to 2.6% per year for OECD countries (EIA 2006; IEA 2006a). As a result, energy demand among developing nations exceeds the global average rate of 1.6%. For example, energy demand growth averages 3.7% per year for non-OECD Asia (including China and India), 2.8% per year for Central and South America, 2.6%...
Redefining Energy Security for the 21st Century
An Empirical Analysis of the Evolution of Energy Security Towards Sustainability

per year for Africa, 2.4% per year for the Middle East and 1.8% per year for non-OECD Europe and Eurasia (IEA 2005; EIA 2006; IEA 2006).

Another central indicator for shifting demand centres is the expected concentration of demand for oil, the world’s most traded commodity (IEA 2004). Although energy demand for all fuel sources will increase the most in developing countries, oil demand in particular is concentrated in non-OECD Asia Pacific. Oil is expected to remain the world’s dominant fuel with global demand rising from 75 mb/d in 2000 to 120 mb/d in 2030 (IEA 2006). Figure 3-3 disaggregates projected oil demand by region between 2005-2015 showing that 60% growth occurs in non-OECD Asia Pacific (IEA 2005; WEF 2006). The concentration of oil demand within a non-OECD region has significant implications for the global supply chain in terms adequate investment in Asia Pacific and geopolitical competition over oil supplies in the Middle East. Heightened security concerns will also arise over transport safety where 20% of global traded oil will flow through the Straits of Malacca to supply Asia by 2030 (IEA 2004).

![Figure 3-3. Changes in Global Demand by Region for Refined Oil Product 2005-2015](image)

*Source: Cambridge Energy Research Associates (CERA) in World Economic Forum (WEF) 2006*

Economic and demographic growth projections for Asia imply that oil demand from these regions may create instability on the oil market (Constantini et al. 2007). The structural shift in demand centres towards Asia has significant implications for the global energy security system. For example, currently, only Japan among many nations in the Asia Pacific region is included in IEA agreements and discussion. And yet, oil demand growth will be focused in China and India. Countries in Latin America, Africa and the Middle East are also showing significant demand growth but remain outside the IEA system. This could create a tense situation of increased competition between developing countries and the OECD. The alternative is to bring emerging economies such as India and China into the IEA system to cooperate over global energy security issues. Rather than been viewed as competition, investments made by China and India into new energy supplies that might otherwise not have been made by the private sector (i.e. Chinese investment into politically sensitive Sudan) may help

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38 The developing countries’ share of global demand will increase for all primary energy sources, except non-hydro renewables although expanding in China and other parts of Asia. By 2030, developing countries are expected to account for: 18% of world nuclear output from 4% in 2002; Coal consumption increases from 46% to 61%, mainly driven by demand in China and India; Developing countries will account for almost two-thirds of the 45-mbd increase in global oil consumption between 2002 and 2030 (IEA 2004, 2005).
alleviate the tight supply situation\textsuperscript{39} (DOE 2006; WEF 2006; Yergin 2006, 2007).

### 3.1.2 Shifting Supply Centres

Due to low cost factors and location of resources a structural shift in supply centres is also expected to occur towards developing countries. Figure 3-4 shows that between 2002 and 2030 more than 95% of the increase in production will occur in non-OECD regions compared to 70% from 1971 to 2002.

![Figure 3-4. Increase in World Primary Energy Production by Region](source)

*Source: IEA 2004*

The largest total production increase will be in the Middle East from the current level of 37% to 53% by 2030 due to the fact that most low-cost fossil-fuel resources are located in Saudi Arabia accounting for 25% of global proven oil reserves (Figure 3-5) (IEA 2004).

![Figure 3-5. Proven World Oil Reserves Excluding Canadian Oil Sands (% of Total: 1212.9 billion barrels)](source)

*Source: IMF 2005d*

\textsuperscript{39} Yergin (2007) indicates that bringing China and India into the IEA system is critical for ensuring global energy security. For consumers in North America, Europe, and Japan, Chinese and Indian investment into new energy supplies is not a threat but should be encouraged, since it will increase future available energy, which is especially important since China and India’s demand will continue to rise (ADB 2005; IEA 2006; EIA 2006).
OPEC countries currently control around 70% of proven oil reserves if Canadian tar sands are included in the total\(^{40}\). Also contributing to the shift in supply centres is that non-OPEC reserves are being depleted at a faster rate than reserves held by OPEC (Figures 3-6). Moreover, OPEC has a significant cost advantage over non-OPEC producers, which is expected to widen as non-OPEC producers try to maintain their reserve base by moving into more costly offshore projects (IMF 2005d).

\[\text{Figure 3-6. OPEC and Non-OPEC Crude Oil Reserves 1970-2002 (% of World Total)}\]

\[\text{Source: IMF 2005d}\]

Due to the disproportionate share of oil reserves located in OPEC countries combined with a faster depletion rate of non-OPEC reserves, future projections indicate that oil reserves will become increasingly concentrated in Middle East and North African countries rising from 70% in 2002 to 80% by 2020 (Figure 3-7). As a result, all other regions in the world will become more dependent on fewer producers concentrated in MENA countries.

\[\text{Figure 3-7. Concentration of Global Oil Reserves in Middle East and North Africa 2002-2020}\]


\(^{40}\) 80% if Canadian tar sands are excluded from the total (IMF 2005d).
As production centres become concentrated in non-OECD countries a fundamental shift in the global supply structure will occur. For instance, oil production from OPEC member states accounted for 54% of global oil production in 1974 falling to a 30% low in 1985 and is currently around 40%. However, in terms of oil production capacity, 15 countries are expected to dominate the future growth of long-term oil supplies (WEF 2006). Table 3-1 gives data for oil production capacity increases showing that global oil supply production (million barrels per day of production capacity) will be concentrated in 15 countries. In 1995 these 15 countries accounted for 50% of the global production capacity but this balance will be tipped when their production capacity reaches 58% of the world total by 2015.

Table 3-1. Oil Production Capacity Increases (Million Barrels Per Day of Production Capacity)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Saudi Arabia</td>
<td>10.2</td>
<td>11.1</td>
<td>13.2</td>
</tr>
<tr>
<td>2</td>
<td>Russia</td>
<td>6.2</td>
<td>9.5</td>
<td>11.3</td>
</tr>
<tr>
<td>3</td>
<td>Iran</td>
<td>3.7</td>
<td>4.2</td>
<td>5.2</td>
</tr>
<tr>
<td>4</td>
<td>Iraq</td>
<td>2.1</td>
<td>2.3</td>
<td>4.0</td>
</tr>
<tr>
<td>5</td>
<td>Canada</td>
<td>2.4</td>
<td>3.5</td>
<td>5.3</td>
</tr>
<tr>
<td>6</td>
<td>Venezuela</td>
<td>3.0</td>
<td>2.9</td>
<td>3.4</td>
</tr>
<tr>
<td>7</td>
<td>UAE</td>
<td>2.3</td>
<td>2.9</td>
<td>3.5</td>
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<tr>
<td>8</td>
<td>Kuwait</td>
<td>1.6</td>
<td>2.5</td>
<td>3.2</td>
</tr>
<tr>
<td>9</td>
<td>Nigeria</td>
<td>2.1</td>
<td>2.9</td>
<td>3.7</td>
</tr>
<tr>
<td>10</td>
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<td>0.4</td>
<td>1.2</td>
<td>3.3</td>
</tr>
<tr>
<td>11</td>
<td>Algeria</td>
<td>1.4</td>
<td>2.2</td>
<td>3.1</td>
</tr>
<tr>
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<td>1.8</td>
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<td>0.4</td>
<td>1.1</td>
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<td></td>
<td>Total Top 15</td>
<td>35.9</td>
<td>47.0</td>
<td>62.8</td>
</tr>
</tbody>
</table>

Source: Adapted from CERA in WEF 2006

This shift in supply centres has significant implications for current energy security policies given that many of these regions are considered politically unstable. The threat of oil used as a political weapon is more prominent now than ever before causing anxiety among industrialized oil dependent nations (Yergin 2006). A central fear among the OECD is the risk of further collusion among oil exporters due to increasing concentration of oil reserves and production, which could distort export prices and delay new investments causing market instability. However, effective collusion can be impaired by different reserve/production ratios between exporting countries (particularly within North Africa and Middle East), with different capabilities and interests to expand supply. For example, countries with less volume potential are typically interested in slower demand growth and higher prices than exporters that can increase revenues by expanding volumes at current prices. However, the ability to expand supply is linked to whether or not adequate investments will materialize – another major source of uncertainty
Redefining Energy Security for the 21st Century
An Empirical Analysis of the Evolution of Energy Security Towards Sustainability

(Constantini et al. 2007). In coming years, increasing supply concentration coupled with heightened competition over fewer resources may aggravate geopolitical tensions. This combined with the fact that a concentration of production centres raises the vulnerability of critical infrastructure and transportation bottlenecks to terrorism, accidents or extreme weather is forcing a re-evaluation of conventional energy security policies and how nations will deal with rising energy insecurity.

3.1.3 Rising Import Dependency
A central driver behind rising competition over energy supply is increasing energy import dependency between OECD and developing Asian countries (Figure 3-8). It is expected that import dependency will continue to rise as indigenous production fails to keep pace with demand. Further straining the situation is that non-OPEC production of conventional crude oil and natural gas liquids are set to peak within a decade as reserves in the UK, Norway and North America deplete. By 2030, the OECD as a whole is expected to import two-thirds of its oil needs compared to 56% today (IEA 2005; IEA 2006a).

![Figure 3-8. Increasing Global Oil Import Dependency](image)

Source: IEA 2005

Import dependency will rise the most in Asia with India and China importing 90% of oil requirements by 2030. Oil supply security is now becoming an important political issue in Asia with India and China establishing strategic oil reserves. Most of the additional imports will come from the Middle East along vulnerable marine transport routes increasing risk to supplies. Furthermore, the concentration of oil production in a small group of countries with large reserves including the Middle East OPEC members and Russia will increase their market dominance and ability to impose higher prices for political ends placing import dependent nations at particular risk (IEA 2006a).

Natural gas import dependency is also expected to increase led by North America and Europe. For Europe, an increasing share of gas demand will be met by imports, via pipeline or in the form of liquefied natural gas (LNG) from increasingly distant suppliers, which will raise investment costs and expose vulnerabilities along a complex supply chain. Currently, approximately half of the European Union’s gas is supplied by Russia, Norway and Algeria. If current trends persist, gas imports will
increase to 80% over the next 25 years (EC 2006; IEA 2006a). The European Union (EU) indicates that unless domestic energy becomes more competitive over the next 20 to 30 years, EU total import dependency will rise from 50% to 70% supplied by some regions threatened by political instability (EC 2006).

3.1.4 Spare Production Capacity

Set against rising global demand lays the burning question, “where will the additional oil come from?” OPEC nations are currently operating at near full capacity and are having difficulty meeting worldwide oil demand contributing to the recent upward trend in oil prices. Recent supply disruptions have also intensified concerns over the declining rate of global oil reserve additions to discoveries since the 1960s (Figure 3-9) (IEA 2005; WEF 2006).

![Figure 3-9. Annual Oil Discovery Versus Annual Oil Production 1963-2002](image)

Source: IEA 2004

In the last decade, discoveries have replaced only half the oil produced. The fall in oil discoveries has been most dramatic in the Middle East plunging from 187 billion barrels in 1963-1972 to 16 billion barrels at the end of 2002 (IEA 2004; NETL 2006). Although, the share of new discoveries for Africa, Latin America and Asia have increased the absolute amount of oil discovered has fallen since the 1970s. The drop in oil discoveries is due to reduced exploration activity in regions with the largest reserves, and a fall in the average size of fields discovered. For example, exploration drilling in the Middle East has been minimal for years because proven reserves are already large. National oil companies in the region therefore have little incentive to appraise existing fields, or explore new ones but rather focus investment into maintaining or increasing already producing fields (IEA 2004).

However, OPEC reserve estimates have been questioned in the past due to the lack of independent source verification. The IEA (2005) has called into question reserve estimates stated by OPEC and MENA. For example, total reserves in many MENA countries did not change in the 1990s despite continued production where official reserves in Kuwait remained at 96.5 billion barrels from 1991 to 2002, even though the country produced more than 8 billion barrels and did not make any important new discoveries during that period. Saudi Arabia also maintains that proven reserves are between 258 to 262 billion barrels over the past 15 years despite production of well over 100 billion barrels (NETL 2007). Although, no new discoveries does not rule out major additions to reserves through extensions and revision, which are common in many oil provinces (NETL 2006).
Although the traditional way of measuring discovery rates can underestimate the total oil resources available for exploitation or recovery, current capacity production is nonetheless meeting growing demand by a narrow margin (Yergin 2006). Figure 3-10 illustrates the narrow margin in which production capacity will meet growing demand assuming a 1.9% annual growth rate of global oil demand to 2015.

![Figure 3-10. Additional Oil Capacity Outpacing Expected Demand by Narrow Margin](image)

*Source: CERA in WEF 2006*

Although the total productive capacity is expected to keep pace with demand until 2015 the supply – demand situation will remain tight placing pressure on a concentration of global producers. Low spare production capacity has significant repercussions on energy security concerns for all nations in the event of a major supply disruption that could not be offset by surge production in the Middle East. The absence of spare production capacity raises the vulnerability of economies around the world in the event of a supply disruption. This heightened risk places upward pressure on oil prices and is one of the key drivers behind current oil price increases. There is also significant concern whether adequate upstream investment will be made by key producers in the Middle East to increase production capacity. This uncertainty is particularly troubling for oil import dependent countries that only expect to see foreign energy dependency rising in the short to medium-term. Box 3 discusses how the lack of investment in the Middle East has resulted in deficient spare production capacity placing considerable stress upon world energy markets and how the lack of adequate investment translates into significant profit losses for oil producers.
Box 3. The Cost of Deferred Middle East Investment

The rate of investment in developing crude oil production capacity in the Middle East is particularly important for world energy markets. Current rates of investment in the Middle East are not high enough to meet the expected gap between global oil demand and production capacity in other parts of the world. Without significant increases in Middle East investment, a shortfall in production capacity will emerge increasing oil price volatility with potential long-term economic repercussions on both producers and consumers. Abundant spare production capacity can help minimize price increases (Giusti 2005). The relatively low level of spare oil production capacity currently available to counteract any unexpected loss of supply has resulted from years of underinvestment in the Middle East placing upward pressure on oil prices (Figure 3-11). This increases the potential that a sudden loss of even a small volume of oil could lead to a sharp increase in prices. (Birol 2006; IEA 2006).

![Figure 3-11. Increasing Oil Prices & Diminishing OPEC Spare Production Capacity 1995 – 2004](image)

Source: Giusti 2005

In the recent past, the Middle East, specifically the Persian Gulf region held almost all spare capacity with Saudi Arabia holding approximately 85% of the total (Giusti 2005). For at least a decade the spare capacity level exceeded 2 million barrels per day acting as a pillar for global energy security because the market had confidence that almost any disruption to oil supplies could be met by surge production. In recent years however, Gulf spare capacity has decreased to less than 2 million barrels per day, concentrated in Saudi Arabia and consisting of hard-to-refine heavy sour crude. This oil generally has limited marketability, since there is not enough global refinery capacity available to process the high sulphur content oil. Moreover, uncertainty over future supply-side infrastructure investments is not limited to Middle East crude oil production. Investment into new refining capacity is urgently needed but is often held up by environmental restrictions and local opposition, especially in OECD countries (Birol 2006). The lack of adequate investment into both upstream production and downstream refining has increased fears over vulnerabilities to oil supply disruptions and market volatility (Giusti 2005; Birol 2006).

Not only does the lack of investment have global repercussions, the cost of deferred investment for MENA could be significant. The IEA (2006) predicts that if upstream investment in each MENA country were to remain constant as a share of Gross Domestic Product (GDP) at the average level of the past decade, a 110 billion USD, or 23% drop in cumulative upstream MENA investment over 2004–2030 would occur. As a result, from 2004–2030, the cumulative value of aggregate MENA oil and gas export revenues could decrease by approximately 1 trillion USD (Birol 2006; IEA 2006).
3.1.5 Infrastructure Investment

One of the most important implications of the shifting demand/supply structure is the need for both upstream and downstream investment into energy infrastructure. Global cumulative energy-sector investment needs are estimated at an unprecedented 20.2 trillion USD between 2005 and 2030. Most of the investment is required in developing nations reflecting the fundamental shift of demand and supply centres towards non-OECD nations (Figure 3-12) (Birol 2006; IEA 2006). It could be argued that the sheer magnitude of investment alone, with the bulk of it needed in developing nations is enough to represent a break from the conventional energy security paradigm, which is primarily comprised of policies and strategies to enhance the western world’s ability to secure oil supply.

![Figure 3-12. Energy Infrastructure Investment Needs 2005 – 2030](image)

Source: Adapted from IEA 2006

Oil Sector

Oil sector investment amounts to 4.3 trillion USD between 2005 and 2030. Three-quarters of total oil investment is expected for the upstream. Upstream investment needs are more sensitive to changes in decline rates at producing fields than to the rate of growth of demand for oil (IEA 2006). The IEA projects that the oil industry’s production capacity will slightly outpace demand through the end of this decade if all infrastructure projects see the light of day. It is far from certain though, that all necessary investment will occur. There has been a surge in oil and gas investment in recent years, but the actual impact of capital expenditure is to an extent superficial since drilling, material and personnel costs in industry have soared, so that in real terms, investment in 2005 was barely higher than in 2000 (NETL 2007). In order to increase the volume of heavy, sour crude being refined into light, sweet petroleum

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41 In 2005 US dollars. This is approximately $3 trillion higher than 2005 IEA projections, primarily due to recent sharp increases in unit capital costs, particularly in the oil and gas industry.

42 Capital spending by the world’s leading oil and gas companies increased sharply in nominal terms over the first half of the current decade and is expected to increase towards 2010. However, the impact on new capacity of higher spending is being offset by rising costs. Expressed in cost inflation-adjusted terms, investment in 2005 was only 5% higher than in 2000 (IEA 2006a).
products, existing facilities will require upgrading, replacement and expansion. At the same time, other downstream industries, specifically pipelines and tankers will also need to be maintained and expanded (IMF 2005a).

Gas Sector

Gas sector investments amount to 3.9 trillion USD from 2005 to 2030. Expansion of the worldwide LNG market will be extremely capital intensive, requiring the development of reserves often in remote regions, liquefaction facilities, transportation, and marketing through re-gasification plants (Dorian et al. 2006). Natural gas was for decades a local or regional industry but is now rapidly becoming a global industry. Plans to transport supplies over 15000 km from source to market may require the most complex supply chain in history (Dorian et al. 2006). Nearly half of all investment in global gas development over the next three decades will be directed toward infrastructure improvement and expansion, including LNG tanker ports and re-gasification terminals located along coastal areas. The Cambridge Energy Research Associates (CERA 2004) predict that over the next 8 years, the world’s gas industry will expand as much as it did over the past 40 years. This unprecedented expansion intends to meet growing demand in Asia and the U.S. prompted by a shift towards cleaner fuels partly in response to the climate change agenda. China alone is planning to develop nine new LNG terminals within the decade (Dorian et al. 2006).

Power Sector

The power sector accounts for 56% of total investment from 2005 to 2030. Investment into the power sector has critical implications for the economic and social development of developing nations where most of the total investment is required. In rural areas where large populations still reside, access to modern energy plays a critical role in reducing poverty and raising the standard of living. The linkage between infrastructure investment as an aspect of energy security and poverty reduction represents an important shift away from the conventional energy security paradigm that may not prioritize social objectives in policy development. However, the inter-relationship between infrastructure investment and poverty reduction is linked to the demand-supply shift away from OECD countries towards developing nations. An expanded scope of energy security, which accounts for broader development goals may pose a challenge to conventional energy security policies that may otherwise only target investment needs to ensure energy supplies reach demand centres in OECD countries able to pay for the service. Therefore, a new understanding of energy security is required calling for an important shift in perspective from national security and market interests towards global energy security and sustainable development goals reflected in international agreements such as the UN Millennium Declaration.

Coal Sector

Total investment requirements for coal are marginal at 3% of the total. Most of this development will occur in developing nations particularly China and India that have abundant reserves. The development of coal also has comparative cost advantages to other primary energy sources and will therefore remain important for developing nations with booming economies. This has important implications from a climate change and pollution perspective since coal is a highly emitting energy carrier. This draws attention to the delicate balance between economic development and meeting environmental objectives which also marks an important break from the conventional energy security paradigm that typically does not account for climate change or sustainability goals.
3.2 Vulnerability & Threat

A second key feature of a structural shift in the modern energy security paradigm is the heightened level of vulnerability and threat upon an increasingly complex and interconnected global energy system. There are two central types of threats: First, the perceived threat of adequate access to energy supply linked to geopolitical competition over resources and the shift of demand and supply centres towards non-OECD countries. Second, the physical threat to the supply chain and critical infrastructure linked to globalizing energy markets and also influenced by the shifting demand/supply structure. As the global energy system integrates, vulnerabilities in the system are more exposed to acts of terrorism, extreme weather events and accidents. The threat of “global terrorism” whether perceived or real, marks a significant break from the conventional energy security paradigm where threats to energy supply were dealt with between governments. With the threat of terrorism elevated to the global scale, the international security context and the implications it has for energy security has taken on a more diffuse and unpredictable character. The central implication of heightened vulnerability and risk, whether it is from a disruption of oil supply or a direct threat to infrastructure, these heightened risk perceptions are passed onto the market in the form of price volatility.

3.2.1 Oil Volatility

Oil market volatility is one of the central threats to a fossil based energy security system. The structural inflexibility of the oil market in the short term, both on the supply side (due to high fixed production costs) and the demand side (due to low price and substitution elasticity) explains the high volatility of oil prices. The slightest imbalance between supply and demand, or the expectation of such an imbalance can profoundly impact prices. Volatility in oil prices, both in the short and long-term creates uncertainty and instability for economies in both exporting and importing countries (Constantini et al. 2007).

Responding to oil price volatility has always been central for modern energy security policies, but the debate now is whether or not, recent oil price hikes will become permanent reflecting deeper structural changes in the global energy system (Evans 2006; JCIF 2006; Toichi 2006). Figure 3-13 shows the volatile nature of oil prices between 1971 and 2005 showing only brief periods of relative stability in the years leading up to the first oil shock of 1973 and between 1985 and 1995, albeit with intermittent shocks.

![Figure 3-13. Real Oil Price 1971-2005 (Quarterly Brent Crude Oil Price Deflated by U.S. Consumer Price Index)](Figure313.png)

Source: OECD 2004
Oil price volatility has been pronounced in recent years compared to other market commodities (Table 3-2). In the short-run, low price elasticity’s of global demand and declining levels of non-OPEC supply make oil prices highly sensitive to supply and demand shifts. Price volatility, compounded by geopolitical tensions, raises uncertainty about underlying price trends, which can depress investment into oil exploration and development. Moreover, OPEC’s low excess capacity, the lowest in three decades will provide little protection against an unexpected oil market disruption (OECD 2004).

Table 3-2. Crude Oil Price Volatility and Other Market Commodities (Standard Deviation of Monthly Percentage Changes)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural raw materials</td>
<td>3.1</td>
<td>2.5</td>
<td>-0.6</td>
</tr>
<tr>
<td>Food and beverages</td>
<td>5.5</td>
<td>3.1</td>
<td>-2.3</td>
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<tr>
<td>Food</td>
<td>6.0</td>
<td>3.5</td>
<td>-2.3</td>
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<tr>
<td>Tropical beverages</td>
<td>6.1</td>
<td>6.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Vegetable oil</td>
<td>6.8</td>
<td>4.8</td>
<td>-2.0</td>
</tr>
<tr>
<td>Minerals and metals</td>
<td>3.3</td>
<td>3.7</td>
<td>0.4</td>
</tr>
<tr>
<td>Gold bullion</td>
<td>6.0</td>
<td>3.7</td>
<td>-2.3</td>
</tr>
<tr>
<td>Crude oil (Brent)</td>
<td>4.4</td>
<td>9.2</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Source: OECD 2004

Market volatility can affect the level of oil prices and inventories in two main ways. First, when the market is volatile, refiners and consumers typically desire a higher level of inventories, which *ceteris paribus*, raises prices in the short run. Second, volatility raises the value of the call option held by oil producers of being able to extract oil from the ground. This increases the opportunity cost of current production and can result in decreased oil supply, unless spot prices rise relative to the futures price to make continuing production and pushing down inventories worthwhile. Higher demand for inventories and reduced supply will thus push prices up. Although the impact of the first channel will be temporary, as inventories adjust to their new higher level, the higher price that results from the second channel will persist as long as the higher level of volatility continues (OECD 2004).

Soaring oil demand and insensitivity to price poses another source of energy vulnerability. After the recession of 2000-2001 oil demand increased among major and emerging economies including Japan, China, India and the U.S. (Kirton 2006). The growing insensitivity of oil demand to price accentuates the potential impact on international oil prices in the event of a supply disruption. Moreover, the share of transport demand, which is price-inelastic relative to other energy services in global oil consumption is projected to rise. As a result, oil demand becomes less responsive to movements in international crude oil prices. The cushioning effect of subsidies to oil consumers contributes to the insensitivity of global oil demand to changes in international prices (IEA 2006a). Current subsidies on oil products in non-OECD countries are estimated to exceed 90 billion USD per year. Subsidies on all forms of final energy outside the OECD are over 250 billion USD per year, equal to all investment needed in the power sector each year on average in developing nations (IEA 2006a). This means that government subsidies used to cushion the impacts of rising oil prices could be invested into infrastructure crucially needed in the power sector to deliver energy to impoverished rural regions and fuel economic growth.

43 Caps, also called “call options,” establish a maximum average purchase price for future oil consumption. They provide full protection from rising prices while allowing the buyer to benefit fully from decreases in oil prices. Caps are usually bought by oil end users. Floors also referred to as "put options," establish a minimum average sale price for future oil production. They provide full protection from falling prices while allowing the buyer to benefit fully from increases in oil prices. Floors are usually bought by oil producers (Sempra 2005).
In recent years, oil prices have nearly doubled with potential implications for the global economy. Many oil-importing countries have offset higher oil import costs by increased value of non-energy commodity exports. The eventual impact of higher energy prices on the macro economy remains uncertain, partly because the effects of recent price increases have not fully worked their way through the system. Nevertheless, the longer prices remain at current levels or the more they rise, the greater the threat to the economies of importing countries. Moreover, an oil-price shock caused by a severe supply disruption would impact heavily indebted poor countries the hardest with increasing evidence of disproportionate effects upon oil dependent developing nations (Bacon 2005; Bacon & Mattar 2005; Bacon & Kojima 2006; IEA 2006a). This signals an important break away from the conventional energy security paradigm towards an international energy security perspective that accounts for the asymmetrical vulnerabilities between industrialized and developing nations to oil volatility.

### 3.2.2 Oil Peaking

Another central threat to a modern energy system fixated on oil is an eventual oil peak. Since oil is a finite natural resource global oil production will inevitably reach a maximum, called “the peak,” after which time production will decline (NETL 2007). The precise date of an oil peak is greatly debated. Nonetheless, the enormous threat of such an oil peak upon the global energy system is widely acknowledged, particularly with the increasing trend of global oil consumption. For instance, global oil consumption has increased by 20% since 1994, and global oil demand is projected to grow by 1.6% per year (EC 2006). This means if the world’s economy grows as expected over the next 25 years, oil demand is projected to increase more than 50% from 80 mbd today to around 120 mbd by 2030 (EIA 2006; IEA 2006). Figure 3-14 shows demand for oil will exceed demand for all other energy sources in 2030.

![Figure 3-14. Global Energy Consumption Projections by Energy Type 1980-2030](image)

Source: EIA 2006

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44 As of March 2007, crude prices hovered around 60 USD/bbl on average. The market was overwhelmingly driven by product prices in the U.S. where strong demand coincided with peak refinery maintenance and several downstream outages. OPEC cuts have further tightened the market. Since September 2007, OPEC has cut output by approximately 1 mbd. Shortages in Alaska and Nigeria, both due to pipeline spills also contributed to further upward market pressure on oil prices (IEA 2007).

45 China alone will be responsible for nearly one-third of escalating oil demand. Consumption may rise from 6.3 to around 13 mbd by 2025 (EIA 2004). Other industrializing countries, especially India and other emerging Asian economies, have become major oil consumers. Demand in the U.S. is also expected to increase reaching two to three times higher than European oil demand in coming years (EIA 2006; Dorian et al. 2006).
The threat of an inevitable oil peak has created much speculation and uncertainty. Table 3-3 lists various projections for ultimate oil reserves and peak years.

<table>
<thead>
<tr>
<th>Source</th>
<th>Affiliation</th>
<th>Year</th>
<th>Estimated Ultimate Reserves</th>
<th>Peak Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hubert</td>
<td>Shell</td>
<td>1969</td>
<td>2100</td>
<td>2000</td>
</tr>
<tr>
<td>Brookout</td>
<td>Shell</td>
<td>1989</td>
<td>2000</td>
<td>2010</td>
</tr>
<tr>
<td>Appleby</td>
<td>BP</td>
<td>1996</td>
<td></td>
<td>2010</td>
</tr>
<tr>
<td>Edwards</td>
<td>University of Colorado</td>
<td>1997</td>
<td>2836</td>
<td>2020</td>
</tr>
<tr>
<td>Schollenberger</td>
<td>Amoco</td>
<td>1988</td>
<td></td>
<td>2015-2035</td>
</tr>
<tr>
<td>IEA</td>
<td>OECD</td>
<td>1998</td>
<td>2800</td>
<td>2010-2020</td>
</tr>
<tr>
<td>EIA</td>
<td>DOE</td>
<td>1998</td>
<td>4700</td>
<td>2030</td>
</tr>
<tr>
<td>Deffeyes</td>
<td>Princeton University</td>
<td>2001</td>
<td>1800-2100</td>
<td>2004</td>
</tr>
</tbody>
</table>

Source: Adapted from Asif & Muneer 2007

Pessimistic projections suggest 2000 to 2010 as the likely target, while optimists cite new non-conventional sources of oil such as tar sands, heavy oil and shale oil delaying a peak in oil production for another 30 to 40 years (Dorian et al. 2006). The pessimists view was bolstered in 2004 when questions were raised about Saudi Arabia’s national oil reserves and whether or not major fields are peaking (IEA 2005; Dorian et al. 2006; NETL 2007). However, even large differences in estimated remaining world oil reserves are not expected to significantly change the general time frame of world peaking. According to the EIA (2005), projections for oil peaking are highly insensitive to the assumption of alternative resource base estimates. For example, adding 900 Bbbl (billion barrels) more oil than had been produced at the time estimates were made to the mean United States Geological Survey (USGS) resource estimate, in a 2% growth case only delays the estimated production peak by 10 years. Similarly, subtracting 850 Bbbl in the same scenario accelerates the estimated production peak by only 11 years. Most predictions are problematic however, because much of the data needed for an accurate forecast falls into one or more of the following categories:

1. Proprietary to companies.
2. State secrets in the major oil exporting countries.

Using differing methodologies and information of widely varying quality, various forecasts have been attempted to determine the likely year of conventional oil production peaking. The range of estimates extends from late last year to denial that it will ever happen. Almost all forecasts are based on differing geological assumptions (NETL 2007).

OPEC representatives have in the past denied that the peaking problem exists. It is speculated that OPEC may believe it is in their self-interest to deny the peaking problem because it may undercut near-term market control. However, such a denial is highly contested since it is well established that production from individual oil fields reach a peak and then decline and regions composed of many oil fields behave similarly (Chatterjee 2006). Source: OPEC needs clear demand signals for spare capacity, Mail & Guardian Online, July 11, 2006; "We in OPEC do not subscribe to the peak-oil theory,” quotation attributed to OPEC acting secretary-general Mohammed Barkindo.

Aside from the debate over the precise time of a peak in production, if it does occur it will present a challenge to energy risk management of tremendous complexity (NETL 2007). If the optimists prevail, new oil supplies will be made available from a combination of price and technology incentives. However, access and development of additional reserves are tightly linked to technical, economic, commercial, and political risks (Dorian et al. 2006). Physical resources are only one consideration while accessibility to reserves may depend on alignment with international oil companies, or how hospitable a policy environment is to foreign investment. The potential threat that oil peaking poses for the global energy system sheds light upon the growing interlinkages between powerful national and corporate interests and how shifting demand and supply centres will ultimately determine the extent of infrastructure investment required.

### 3.2.3 Conflict & Terrorism

Oil volatility and peaking are threats that arise internally from the energy system because the system is oil dependent. This has clear implications for energy security policies on how to reduce the threat that oil poses by eliminating dependency. Threats also arise externally such as the potential for armed conflict or terrorism. Figure 3-15 shows that in the past 50 years, seven out of nine supply disruptions of over 2.0 mbd were associated with armed conflict. This is not to say that conflict was the sole cause of oil supply disruptions in all cases, but that a number of inter-related factors including conflict contributed to a disruption in supply. This is a subtle, but important distinction to make recalling the previous argument that drawing a direct cause and effect link between observed political events, supply disruptions and perceived impacts upon the industrialized world has led to disastrous energy security policies. The energy security focus on Middle Eastern oil supplies was significantly influenced by the Iranian Revolution in 1978-1979 resulting in the highest gross supply loss of 5.6 mbd. Hurricanes Katrina and Rita in the Gulf of Mexico however caused the most recent supply disruptions.

![Figure 3-15. Global Conflict & Energy Supply Disruptions 1956-2005](image)

Note: Natural gas in millions of barrels of oil equivalent. Magnitude of supply shortfall is the peak gross supply loss excluding increases of other oil-producing countries. The IEA calculation uses a trigger of 7% net loss of available IEA supplies. Average daily supply loss over disruption period is lower than the gross peak supply loss.

*Source: IEA, U.S. Management Minerals Service, CERA in WEF 2006*
The rising threat of armed conflict and increased frequency of extreme weather events illustrates an important connection that is missed by conventional energy security policies. Although historically viewed to be unrelated there is greater understanding about the linkages and positive feedback between energy use, climate change, environmental degradation and armed conflict (Munasinghe 1999; Kaghram et al. 2003; Abbot et al. 2006; Elhefnawy 2006; IPCC 2007). For example, regional and social turmoil aggravated by poverty and environmental degradation may increase the risk of armed conflict in key producing areas having crucial implications for energy security from a multi-dimensional perspective. Not accounting for how these factors intersect and influence each other may be one the greatest shortcomings of the conventional energy security paradigm.

Along with conventional armed conflict the threat of terrorism is a major concern particularly for vulnerable energy infrastructure. Although terrorism has always been a concern, September 9-11 ushered in the “war on terrorism” elevating the scope of imminent threat (both perceived and actual) to the global scale. Figure 3-16 indicates that there is an increasing trend of terrorist attacks rising from 1272 in 1998 to 4924 incidences in 2005 representing an almost fourfold increase within six years.

Figure 3-16. Total Annual Number of Terrorist Attacks Worldwide 1998-2005

Source: Memorial Institute for the Prevention of Terrorism (MIPT) in Blinc et al. 2007

Figure 3-17 indicates that between 1998 and 2005 the highest number of incidences of terrorist attacks occurred in the Middle East. The Middle Eastern region as a whole has a volatile geopolitical situation with numerous conflicts over past decades. The oil factor cannot entirely be ruled out in some conflicts nor however, should it be considered the only factor. In any event, there are serious concerns over oil security in countries like Iraq where infrastructure is regarded as legitimate targets for radical elements (Asif & Muneer 2007).

48 The Memorial Institute for the Prevention of Terrorism (MIPT) is a non-profit think tank funded through the Department of the U.S. Homeland Security’s Office of Grants and Training (G&T) acting under the direction of US Congress. URL: http://www.mipt.org
3.2.4 Critical Infrastructure

Energy systems are considered critical infrastructure and concern over reliability and vulnerability has grown in recent years with power blackouts in the United States, Europe and Russia. Moreover, China, India and other developing nations face chronic shortages of electric power calling attention to the desperate need for adequate investment particularly for those regions without access to modern energy. The rising incidences of global terrorist attacks have also increased the perceived threat to power stations, refineries, transmission lines, pipelines, shipping, distribution facilities, and other facilities, which collectively represent billions of dollars (O’Brien 1997). Figure 3-18 illustrates the relative risks for segments of a petroleum system shown as high, medium and low.

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49 The Homeland Security Act of 2002 and the USA Patriot Act defines critical infrastructure as “systems and assets ... so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters” (Public Law 107-56(e)). Some of these systems include food, water, agriculture, health and emergency services, energy (electrical, gas and oil, dams), transportation (air, road, rail, ports, waterways), information and telecommunications, banking and finance, postal and shipping, and national monuments and icons (Brown et al. 2003).
Figure 3-18 indicates that all points of end-use are considered high risk posing a threat for human populations. For instance, petroleum products are stored in large tank farms normally located near market centres that service dense populations. Other infrastructure may have less risk on human populations but pose significant economic and environmental risks such as oil pipelines that are nearly impossible to completely protect due to complex networks spanning large distances. The Alaskan oil pipeline is one example that is essential for the U.S. economy but is impossible to defend. Although differing in relative risk, disruptions to almost any part of the system is a risk to the economy along with public and environmental health\textsuperscript{50} (Brown et al. 2003).

The increasing integration of energy systems also raises the magnitude of impact arising from a disruption. For example, a disruption to a natural gas pipeline affects not only businesses and households that use gas for heating, cooking or industrial process, but also power plants that may use gas to generate electricity (Brown et al. 2003). The heightened vulnerabilities of an integrated system were exposed when Hurricanes Katrina and Rita hit the Gulf of Mexico in 2005 causing the first integrated energy crisis of the 21\textsuperscript{st} century (i.e. impacting the physical connections between gas and power, oil refineries and power and distribution systems)\textsuperscript{51} (WEF 2006). As a result, energy security can no longer only be concerned with oil supply but must now include the entire infrastructure of energy supply that supports the global economy. Moreover, most of these systems were not designed for security against terrorism or the severity of storms in recent years such as Katrina or Rita (Yergin 2006; WEF 2006). What also intensifies the risk to vulnerable infrastructure is rising global dependence on new energy supply from places where security systems are not yet established such as the oil and natural gas fields offshore West Africa and in the Caspian Sea (Yergin 2006). The recent terrorist

\textsuperscript{50} E.g. A nuclear facility fallout could render a large geographic area uninhabitable; disruptions to major power plants or transmission lines could force the electric system to rely on less efficient, greater emitting power plants; an accident along a marine transport route could destroy sensitive ecosystems and natural resource based livelihoods, etc.

\textsuperscript{51} Hurricanes Katrina and Rita brought a new perspective to energy security by demonstrating how fundamental the electric grid is to everything. After the storms, Gulf Coast refineries and the big U.S. pipelines were unable to operate not because they were damaged, but because they could not get power (Yergin 2006).
attacks on the processing facility at Abqaiq in Saudi Arabia illustrate the potential threat of terrorism on critical energy infrastructure\textsuperscript{52} (Birol 2006; Deutch & Schlesinger 2006).

The regional integration of gas markets in the EU is another example demonstrating the need to expand the scope of energy security to account for the entire infrastructure network. The gas supply infrastructure is even more vulnerable to deliberate attack than petroleum infrastructure because gas requires compression, or cryogenics to store and move the product. High-pressure pipelines or liquefied natural gas (LNG) tankers are used to transport gas, both of which are vulnerable to attack. LNG facilities are also more expensive and time consuming to construct than oil infrastructure with implications for risk premiums for investment. The potential threat to critical infrastructure has direct consequences for the consumer. The vulnerabilities in the gas supply system were illustrated in August 2000, when a gas pipeline rupture and explosion caused by corrosion killed 12 people leading to significant increases in gas prices in California. This exacerbated the electricity crisis at the time highlighting the interdependency of energy infrastructure (Farrell et al. 2004).

### 3.2.5 Strategic Transport Routes

Another factor contributing to heightened vulnerability and threat is the growing reliance on strategic transportation channels where almost all the world’s traded oil and gas flows. There are approximately 4000 tankers in operation all vulnerable at high seas especially when passing through narrow straits, hazardous areas or other geographic “chokeholds” (Asif & Muneer 2007). Figure 3-19 illustrates some of the world’s most strategic oil transport channels showing how global shares of transported oil will increase the most for the Straits of Hormuz and Malacca comprising 56% of global traded oil by 2030. This reflects the growing concentration of energy supply in the Middle East and the shifting demand centres towards Asia. With more than half the world’s total oil supply moving through only two channels the energy security implications are enormous.

![Figure 3-19. Map of World’s Most Important Marine Energy Transport Routes](image)

\textbf{Source: IEA 2004}

\textsuperscript{52} In February 2006, attempts were made to destroy the Abqaiq processing facility in Saudi Arabia where 6.8 million barrels per day of oil (two-thirds of total Saudi production) are processed before export (Deutch & Schlesinger 2006).
Table 3-4 summarizes key features of the straits shown above along with other important marine transport routes. The description of each route illustrates high vulnerability due to physical characteristics such as narrow passageways. Important pipeline systems that are also highly vulnerable and nearly impossible to protect include the Druzhba pipeline where 1.2 mbd of Russian crude oil flows to Europe, the Baltic pipeline carrying 1 mbd of Russian crude to Baltic Sea ports and the Sumed pipeline, which carries 2.5 mbd between the Red Sea and the Mediterranean (IEA 2004).

**Table 3-4. Characteristics and Flows of Key Marine Energy Transport Routes**

<table>
<thead>
<tr>
<th>Location</th>
<th>Description</th>
<th>2002</th>
<th>2030</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Volume Oil (mbd)</td>
<td>Share of global net trade %</td>
<td>Volume Oil (mbd)</td>
<td>Share of global net trade %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gas (bcm)</td>
<td>(%)</td>
<td>Gas (bcm)</td>
<td>(%)</td>
</tr>
<tr>
<td>The Straits of Hormuz</td>
<td>Located at the mouth of the Persian Gulf is the world's most important maritime oil-shipping route.</td>
<td>15 mbd</td>
<td>44%</td>
<td>43 mbd</td>
<td>66%</td>
</tr>
<tr>
<td></td>
<td>Inbound and outbound lanes are 3 km wide with a 3-km buffer.</td>
<td>28 bcm</td>
<td>18%</td>
<td>230 bcm</td>
<td>34%</td>
</tr>
<tr>
<td>The Straits of Malacca</td>
<td>The principal oil route in Asia (50% of China’s, 80% Japan’s and South Korea’s oil flows) located between Indonesia, Malaysia and Singapore.</td>
<td>11 mbd</td>
<td>32%</td>
<td>24 mbd</td>
<td>37%</td>
</tr>
<tr>
<td></td>
<td>2.5 km wide at narrowest point.</td>
<td>40 bcm</td>
<td>27%</td>
<td>94 bcm</td>
<td>14%</td>
</tr>
<tr>
<td>The Suez Canal</td>
<td>Connects the Red Sea with the Mediterranean.</td>
<td>1.3 mbd</td>
<td>32%</td>
<td>24 mbd</td>
<td>37%</td>
</tr>
<tr>
<td></td>
<td>Closure would force tankers to take the much longer route around the southern tip of Africa.</td>
<td>4 bcm</td>
<td>27%</td>
<td>94 bcm</td>
<td>14%</td>
</tr>
<tr>
<td>Bab el-Mandab passage</td>
<td>Connects the Red Sea with the Gulf of Aden, transports oil en route to Suez Canal and Sumed pipeline.</td>
<td>3.3 mbd</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>In 2002, an attack on the French tanker Limburg off the coast of Yemen highlighted the importance of this chokepoint to world oil supplies.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Bosporus/Turkish Straits</td>
<td>Connects Black Sea with the Mediterranean transporting crude oil from ports on the Black Sea.</td>
<td>3 mbd</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-km-long and less than 1 km wide at the narrowest point.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Commercial shipping has the right of free passage under the 1936 Montreux Convention but Turkey has imposed restrictions on oil-tanker transit for safety and environmental reasons.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Adapted from IEA 2004
As world energy markets increasingly rely upon distant sources of supply from unstable regions, the geostrategic importance of vulnerable transportation routes and related risks to transport infrastructure will rise. This perceived risk is reflected in oil market volatility and may become a permanent fixture in the international energy market. The world is becoming more energy interdependent and will require collaboration among suppliers, consumers, corporations and governments. The sheer scale and complexity of the global energy trade poses a fundamental challenge to conventional energy security policies that reflect national security interests in the context of a far different 1970s era than the situation today.

3.3 Geopolitical Tension

A third key feature of a shifting energy security paradigm is rising geopolitical tension. This is closely linked with the tight balance between demand and supply and growing competition over fewer resources. Unrelenting energy demand by China and India and the rise of Russia as a global gas exporter is changing the geopolitical landscape across the globe. The shift of the demand/supply structure has clear implications for geopolitical dynamics where strong economic growth in Asian countries will also increase political influence and market power in global energy markets. Geopolitics has always been a defining feature of the conventional energy security paradigm, but a host of new and influential players are now emerging.

3.3.1 Shifting Alliances

The geopolitical landscape has changed profoundly in the past 15 years. Until the end of the Cold War international politics was dominated by the U.S. and the USSR. With the demise of the Soviet Union, the world anticipated that the U.S. would largely dominate global politics. Although, the United States has maintained its economic and military superiority new powers are emerging fuelled by rapid economic growth. This will inevitably shape the global political order with new alliances that may reflect interests fundamentally different than western interests that have dominated international politics in past decades (Ehtesharmi & Behrendt in WEF 2006).

As a result, managing the global transformation and securing global stability are two of the most important challenges facing the international political system. It is uncertain what form the global order will take. Key drivers that will shape the outcome are 1) the distribution of military power in the global system, 2) converging and diverging political interests, 3) the economic potential of current and emerging powers and 4) cultural influence (Ehtesharmi & Behrendt in WEF 2006). The combination of these drivers and the dominance of one over others will shape the nature of future alliances. Table 3-5 describes the fundamental shift in the geopolitical landscape in recent years and summarises the following potential scenarios for a future world order: 1) Assuming the U.S. retains its military and economic superiority current and emerging powers such as Europe, China, India and Russia revolve in shifting alliances around the United States; 2) If power becomes fragmented throughout the global system, the geopolitical landscape may be determined by opportunistic ad-hoc alliances among global powers; 3) If cultural affiliation becomes the dominant driver Europe could potentially become the centre for global policy coordination and alliance building due to close proximity of individual European countries to all other parts of the world; 4) Emerging powers primarily from the East may engage more actively to build new alliances among themselves, based on growing global ambitions and a common rivalry to the West (Ehtesharmi & Behrendt in WEF 2006).
Shifting geopolitics and energy demand and supply influence each other. For example, during the Cold War, securing oil supply from the Middle East was a major priority for the U.S. and NATO allies. This geostrategic goal was underpinned by the Carter Doctrine: “An attempt by an outside force to gain control of the Persian Gulf region will be regarded as an assault on the vital interests of the United States of America, and such an assault will be repelled by any means necessary, including military force” (Carter 1980). The demise of the Soviet Union however, changed the geopolitical options available to access energy allowing for a diversification in supply sources. The security interest of the Newly Independent States (NIS) in the Caucasus and Central Asia after reducing their dependency on Russia gave the U.S. an opportunity to secure a foothold over energy supplies in the region. In turn, the U.S. brought in massive amounts of economic and military aid thus influencing the U.S. geopolitical agenda. At the same time, the U.S. has also focussed on the oil-rich regions of Africa (WBGU 2004).

Shifting energy demand and supply sources directly bear upon the geopolitical agenda of nations and vice versa. Energy demand for instance is now shaping the geopolitical agenda of Asia. The diplomatic, strategic, and trading focus of Asian states can be expected to shift due to growing energy import requirements. This may lead to a strengthening of economic and political ties among individual Asian states, Middle Eastern oil-exporting countries and African oil states. These links could pose new challenges to the West both in terms of arbitrating regional conflicts and rivalry for energy supplies, especially in times of supply disruption, conflict, or other emergencies. Also, China’s proactive oil diplomacy and foreign oil and gas investment campaign has raised concerns that its growing need for oil, could make China susceptible to pressures from oil-producing states seeking sophisticated weapons systems or weapons of mass destruction (Jaffe 2004). The central point to draw is that geopolitics and energy demand and supply directly influence each other with the current situation highly uncertain. The only clear recognizable pattern in the interim is a heightened level of geopolitical tension over more geographically concentrated energy resources.
3.3.2 Resource Rivalry

Geopolitical maneuvering to secure increasingly scarce oil resources is driving current energy security strategies\(^{53}\). This is due to the uneven distribution of fossil fuel resources on which most countries rely. What compounds this problem is that oil and gas reserves in non-Middle Eastern countries are being depleted more rapidly than those of Middle Eastern producers. If production continues at the present rate many of the largest non-Middle Eastern producers (in 2002) such as Russia, Mexico, U.S., Norway, China and Brazil may cease to be relevant players in the oil market in less than 20 years. At that point, the Middle East will be the only major reservoir of abundant crude oil. As a result, within 20 years four-fifths of oil reserves could be concentrated in the Middle Eastern countries with the largest share in Saudi Arabia (Asif & Muneer 2007).

Outside of Saudi Arabia, which holds the largest reserves of any country at 260 billion barrels, Iraq ranks second containing an estimated 115 billion barrels\(^ {54}\). Iraqi supplies however, face continuing security concerns (Deutch & Schlesinger 2006; Asif & Muneer 2007). Rising geopolitical risks in the world’s major oil producing regions including Middle East, Eurasia, and Latin America combined with the depletion of oil and gas resources in the United States and Europe have forced energy dependence upon potentially unstable supply regions. The ongoing crises in the Middle East and Iraq, political unpredictability in Iran, growing domestic problems in Saudi Arabia and the perceived terrorist threat posed by Islamic fundamentalists make the Gulf region increasingly unattractive as a source of supply. Nonetheless, the Gulf is expected to remain the main supplier of oil for the foreseeable future (WBGU 2004).

In the immediate term it may be necessary to search for new oil supplies including West African nations such as, Angola, Equatorial Guinea, Nigeria, and Chad. The Caspian region is also expected to contribute to world oil output over the next two decades where proven reserves in Azerbaijan, Kazakhstan, and Turkmenistan exceed 30 billion barrels (the equivalent of North Sea deposits already extracted). Russia also aims to become a major producer of oil, targeting an increase in output from nearly 8 mbd to 10–14 mbd by 2020 (Dorian et al. 2006; WEF 2006). In the mid to long-term, the Caucasus and West Africa could form an important supplementary source of energy supplies alongside the Gulf region. However, there is significant potential for inter-state conflict in the Caucasus-Caspian region, which is a sensitive geostrategic region where U.S., Russian and Chinese interests collide. China is seeking to gain access to energy sources in Kazakhstan viewed as a direct threat to U.S. interests in the region (Deutch & Schlesinger 2006). Nevertheless, the construction of a pipeline from Kazakhstan to China is being pursued as a strategic objective in response to rising energy demand in China. There is also an assumed link between the military conflict over Chechnya and Russia’s strategic plans for oil pipelines. And another potential source of conflict is the major oil and gas seabed reserves where the five Caspian seaboard countries have failed to agree on the distribution of oil and gas rights. Geopolitical tension is also rampant in the South China Sea where seven different states are in dispute over oil and gas rights. Similar conflicts over rights of ownership have arisen in offshore areas of the Persian Gulf, the Red Sea, the Timor Sea and the Gulf of Guinea (WBGU 2004).

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\(^{53}\) E.g. The Japanese and Chinese have tried to convince Russia to move East Siberia oil to either Daqing, China or Vladivostok, Russian Far East, making it available to Japan. Japan’s interest in the Siberia field for energy security is so pronounced, Japan has offered billions of dollars towards social projects in Russia in return for selection of the Pacific coast route (Yergin 2006). The recent Iran–China agreements under which China plans to purchase $50 billion worth of Iranian oil and gas; in return, Iran expects China’s support in the United Nations’ Security Council (Dorian et al. 2006)

\(^{54}\) Other estimates rank Canada and Iran as having the 2 and 3 most oil reserves at 178.8 and 132.5 billion barrels respectively “Worldwide Look at Reserves and Production,” Oil & Gas Journal 103: 47 (December 19, 2005), pp. 24–25.
The current situation is tense with potential for geopolitical conflict more pronounced now than in previous decades. The sheer number of powerful groups including industrialized nations, emerging economies and powerful corporations competing over energy resources spanning the entire globe is unprecedented. Figure 3-20 illustrates global competition over energy supplies. Striped circles show strategic supply sources of the United States with competition from China, India, Russia and the EU.

Figure 3-20. Competition Over Energy Resources Between United States, China, India, Russia & EU


3.3.3 Among Giants: Energy Dependence in China & the United States

Slated to be the greatest rivalry in coming years is the rise of China as a central challenge to U.S. geopolitical dominance. Commenting on the emerging geopolitical situation between the U.S. and China, Henry Kissinger remarked on the diplomatic significance of the difference between America’s and China’s intellectual games chess and go;

“Chess has only two outcomes: draw and checkmate. The objective of the game is absolute advantage—that is to say, its outcome is total victory or defeat—and the battle is conducted head-on, in the centre of the board. The aim of go is relative advantage; the game is played all over the board, and the objective is to increase one’s options and reduce those of the adversary. The goal is less victory than persistent strategic progress”.

- Kissinger 2004 –

Nowhere are the implications of increasing energy dependency more evident from both a national and global security perspective than for the world’s two largest oil consuming nations, the United States and China. Figure 3-21 shows the demand for oil between these two nations comprises around two-thirds of the world’s total demand for oil. Both nations have abandoned the idea of energy independence and are now adjusting their energy policies to reflect the growing need to integrate into the global market (Downs 2006; Deutch & Schlesinger 2006). The prospect of these two nations competing for scarce oil supplies in a tightly balanced energy market has geopolitical repercussions for the entire world.

![Figure 3-21. Comparative Annual Growth in Oil Demand Between World, U.S., China 1981-2007](source: EIA 2006, Short-term Energy Outlook, February)

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57 China is aligning itself in the Middle East (e.g., Iran and Saudi Arabia) and Africa (e.g., Nigeria and Sudan). Chinese interests in securing oil and gas supplies in Central Asia most notably Kazakhstan is viewed as a direct challenge to U.S. influence in the region (Deutch & Schlesinger 2006).
3.3.3.1 The United States

Over the last fifty years, U.S. oil consumption has grown continually except for a period during the late 1970s and early 1980s. In contrast, U.S. oil production has been in decline since the early 1970s (Figure 3-22). As a result, net imports of crude oil have been continually on the rise since 1982. Although efforts were made to reduce demand and therefore imports, oil import dependency is 60% and rising (Deutch & Schlesinger 2006).

![Figure 3-22. U.S. Oil Production, Consumption & Imports 1949-2005](source: EIA 2005)

The U.S. is now confronting what it sees as its own “energy crisis,” and is seeking a new direction for its’ energy security policies that extend beyond traditional goals for self-sufficiency. Accelerating oil demand throughout 2004 and 2005 and rising prices highlighted the vulnerabilities of U.S. oil dependency. High natural gas prices in the U.S. are also evidence of a tightly balanced gas market that leaves consumers vulnerable to supply disruptions or weather-driven increases in demand. The United States is now integrating with an emerging global gas market to bring in new supplies forcing the country to reconsider its energy security agenda now and into the future (WEF 2006). The heightened priority now given to energy security from a geopolitical perspective is well reflected in a recent assessment of U.S. national security and oil dependency conducted by an Independent Task Force under the auspices of the U.S. Council on Foreign Affairs58 (Box 5).

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The rising import dependency of the United States, a country with 4.6% of the world’s population but consumes 25% of global oil supply will need to reconsider its’ energy strategy in the context of maintaining geopolitical dominance. The demise of the Soviet Union increased energy options for the United States, which allowed expansion into the Newly Independent States (NIS) in the Caucasus and Central Asia. At the same time, the U.S. has also focussed on the oil-rich regions of Africa. However, the military threat of the Soviet Union has now been replaced by the economic rise of Asia. In response the U.S. geopolitical strategy appears to be pursuing several objectives:

➤ Safeguarding energy supplies through the diversification of sources and transportation routes.

➤ Preventing political and military control of production areas and transportation routes from rival powers such as Russia and China, potentially hostile states (Iran), or local warlords who could disrupt highly vulnerable transportation routes through terrorist acts.

➤ Developing its position of strength vis-à-vis potential economic rivals (WBGU 2004).

Foreign policy and national energy security will increasingly converge in order to manage the consequences of rising energy dependency (Deutch & Schlesinger 2006). However, energy vulnerability is not only a U.S. preoccupation. It is a common aversion among most G8 members along with other energy import dependent nations. Recent policy shifts and ongoing debates continue in Japan, China and Great Britain about how best to manage a future of energy dependency and risk (Downs 2006; Evans 2006; Kirton 2006).

3.3.3.2 China

With 1.3 billion people and growing rapidly China will have more impact on the future world energy industry than any other country. China surpassed Japan in 2005 as the second largest consumer of oil behind the United States, and is currently the largest producer and consumer of coal. On its present course China may approach the United States in carbon emission levels by 2025, with 6700 million

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59 West Africa produces 15% of U.S. oil imports expected to rise to 25% within the next ten years through the expansion of production plants and construction of a pipeline between southern Chad and the Atlantic ports (The Economist 2002 in WBGU 2004).

60 Energy vulnerability, measured by the market price of West Texas Intermediate (WTI) crude oil on the month forward contract, has been a coalescing force for G8 nations where Summits that were given high attention and produced results occurred in years with the largest oil price spikes (1979-1980). Although, similar Summit cooperation on energy issues did not occur during other oil shock periods (1991, 1997) (Kirton 2006).
metric tons of carbon dioxide projected to be released that year according to the EIA (2004). In the early 1990s, China abandoned plans for energy self-sufficiency recognizing that the country's demand for energy far surpassed domestic supplies. By 2005, China needed to import approximately 3 million barrels of oil per day (Figure 3-23).

![Figure 3-23. China's Oil Import Dependency 1990-2005](chart)

Source: IEA Monthly Oil Market Report (Various issues) in Downs 2006

China is now attempting to diversify its' oil supply currently importing from more than 20 countries around the world including Russia, Central Asia, Sudan and South America. It is also shifting emphasis towards domestic energy production announcing the most ambitious nuclear development plans in the world, aiming to construct 24 to 32 new nuclear reactors by 2020 (Dorian et al. 2006). Box 6 briefly discusses how energy security has become a core government priority, which is shaping the country’s foreign policy strategy reaching across the globe to secure new sources of supply.

Box 5. Chinese Foreign Policy Realignment – A Challenge to the US?

A central aspect of energy security for China is access to sufficient energy supplies to protect the government's core objectives. These include continued economic growth, the prevention of Taiwanese independence, China's continued emergence as a global power, and the survival of the Chinese Communist Party (CCP). In order to achieve these objectives China's foreign policy shows increasing alignment with oil exporting nations including Iran, Saudi Arabia, Sudan and Kazakhstan posing a challenge to US interests in Central Asia. Chinese national interests are strongly shaping its foreign policy in order to secure oil supplies. Oil security is directly linked to core national interests: First, oil is necessary for economic growth because there are no efficient and cost-effective substitutes for gasoline, diesel, and jet fuel for transportation. Second, oil is required to power the military; inadequate supplies could hamper China's efforts to prevent Taiwan's permanent separation from the mainland. Third, because oil is a source of both economic and military power, it underpins China's rise to great power status. Fourth, all of the elements above help bolster the legitimacy of the CCP (Downs 2006).

It has been argued that the most important factor affecting China’s peaceful rise to international pre-eminence is not Taiwan's independence, but the global competition for energy resources61. China has become increasingly aware that domestic energy security is linked to international energy security and foreign policy. And although China is aligning itself with the Middle East (Iran, Saudi Arabia) and Africa (Nigeria, Sudan) it has not taken a clear role in facilitating regional cooperation (Downs 2006). However, China’s recent shifts in foreign policy arise from national security interests – a central feature deeply embedded in the conventional energy security paradigm.

61 Attributed to Li Junru, vice president of the CCP’s Central Party School (Downs 2006).
As China realigns its foreign policy agenda to pursue new sources of supply, the U.S. and other major powers are concerned about rising investments by Chinese oil companies into new energy assets. The concern is that these actions will remove energy resources from the competitive market, which may constrict supply causing an increase in world prices. However, in terms of value and volumes, China’s overseas petroleum investments are limited. For instance, between the early 1990s and 2005, China’s cumulative overseas investment in oil and gas supply was 7 billion USD averaging less than 600 million USD a year. The total equity oil secured is around 400 thousand barrels per day amounting to 15% of China’s total crude imports, 11% of its domestic oil production, 6% of its current oil consumption, 2% of current U.S. oil consumption and less than 0.5% of global oil production.

In comparison, overseas equity oil of the three largest U.S. companies (Exxon Mobil, Chevron, and ConocoPhillips) is 3.9 mbd, around 35% of total U.S. imports and 71% of total liquid production for the three companies. From this perspective, the impact of China’s overseas petroleum investments on global energy markets is limited (DOE 2006). Moreover, since China is expected to consume the vast majority of its resources, the effects of these purchases should be economically neutral. Even if China’s equity oil investments remove assets from the global market, in the sense that they are not available for resale, these actions only displace what China would have otherwise purchased on the open market (DOE 2006).

China is also seeking to develop resources in locations such as Sudan, where most private commercial interests are unwilling to invest. From a global perspective this may be an advantage because China may enlarge the total global oil supply since the private sector would not have invested into these high-risk areas. However, where tension may arise is that China has invested into countries like Uzbekistan, Sudan, and Burma, whose regimes are suspected of terrorism therefore openly violating the strategic interests of the United States. Therefore, China’s tolerance for despotic regimes may bring them into conflict with U.S. foreign policy. The key implication here is if China has assets in these countries, this increases the likelihood that it will intervene to protect its investments (DOE 2006).

Clearly, the potential for conflict exists between China and the U.S. as each nation pursues its own energy security agenda. However, for China, the US, and other major powers, national security interests will continue to blend with broader foreign policy objectives in a globalizing energy market (Downs 2006). As a result, the perception of energy security falling within the sole domain of national security will be challenged as markets expand and supply chains integrate revealing the economic interdependencies and shared risks between nations.

### 3.3.4 Politics of Investment

What makes interdependency and shared risk more apparent is the need for both upstream and downstream investment. The linkages between inadequate investment, low spare production capacity and high oil prices were previously discussed. A key factor that influences investment decisions and energy markets in general are political interests. Consuming countries will become more dependent on oil and gas imports from key suppliers such as Russia and the Middle East. However, there is considerable uncertainty over the pace at which investment in these region’s upstream industry will occur, how quickly production capacity will expand and, given rising domestic energy needs, how much of the potential increase in supply will be available for export (Birol 2006). Moreover, foreign investors in oil will face a world of declining super giant fields and a shift towards less accessible and more costly reserves in parts of the former Soviet Union, Asia, Africa, along with offshore regions in

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62 The IEA (2006) indicates that rapidly expanding populations, steady economic growth and heavy subsidies will continue to drive up MENA energy demand, which is projected to grow by 2.9 % on average per year between 2006 and 2030. As a result, demand will more than double from current levels. The biggest contributors to demand are expected to be Saudi Arabia and Iran accounting for 45 % of MENA energy demand in 2030.
If global oil prices remain high, producers in many countries may demand higher financial concessions from buyers, leading to unattractive investment climates. Expenditures in new oil exploration activities did not rise significantly in 2004 despite higher oil prices, as many oil corporations remember the unexpected price declines of the 1980s causing lower rates of returns on many investments (Dorian et al. 2006).

Government policies, geopolitical factors, unexpected changes in unit costs and prices, and new technology all affect the opportunities and incentives for private and publicly owned companies to invest in different parts of the energy-supply chain. From a geopolitical perspective, the investment decisions of major oil and gas exporting countries are critical since they will affect the volume and cost of imports for consuming countries. However, the ability and willingness of major exporters to increase investment to meet global demand is highly uncertain (IEA 2006a). A case in point is whether future investment into Russia’s gas industry will be sufficient to maintain current export levels to Europe and begin exporting to Asia (Box 4). For instance, vast oil and gas resources in Central Asia are constrained mostly to the old Soviet pipeline network in and out of Russia. The only new route, which avoids Russian territory, is the Baku-Ceyhan oil pipeline, which took years of U.S. leverage and negotiations to move forward. The Baku-to-Ceyhan pipeline is outside of Russia’s national oil company - Transneft’s63 control but the pipeline crosses Russian territory and is shipped from a Russian port (Dorian et al. 2006).

It is therefore not necessarily a question of sufficient reserves below ground, but the investment environment influenced by political interests that determines if necessary investments are made (Giusti 2005). However, if access to resources is taken away from the market and placed under control of governments, the ability to supply energy markets becomes a government decision rather than a market decision. It could be argued that government decisions can often act in the best interests of individual nations or political ideologies rather than for consumers. If this is the case, than the intrusion of politics into the energy market may compromise the collective security of consumers and producers due to political whims and disruptive policies based on non-energy goals (NETL 2007). Consuming countries may also face the risk that producing countries will use their dominant market position to raise prices or withhold supplies for political reasons. For example, Russia’s decision to cut off gas supplies to Ukraine in early 2006 calls into question its reputation as a reliable supplier and has raised

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63 Oil Transporting Joint Stock Company was founded by the Government of the Russian Federation August 14, 1993, and is the legal successor of the USSR Ministry of Oil Industry Main Production Department for Oil Transportation and Supplies (Glavtransneft). http://www.transneft.ru/About/Default.asp?LANG=EN
doubts over how Europe would deal with a prolonged disruption of supplies (Birol 2006).

Infrastructure bottlenecks are common especially in oil and gas. Exploration for new hydrocarbon supplies has extended to remote regions with poor access including West Africa, Siberia, and the Caspian Sea region. As pipelines and other infrastructure networks extend across remote areas to access new supplies, nations will become linked both through financial agreements and physical infrastructure. This calls for a regional energy strategy to be taken marking a shift away from national security strategies that prevailed in past decades. Increased risks to vulnerable cross-border infrastructure could act as a catalyst for regional political cooperation. On the other hand, it could aggravate geopolitical tensions if countries maintain a national security interest based position. Given that energy supply and production centres will become more concentrated in non-OECD countries and the rising energy dependency of affluent Europe and North America, the question of who will bear the costs for necessary infrastructure investment will have important implications from a geopolitical and industry stakeholder perspective. This may result in newly formed alliances or a collision of national and corporate interests in the international energy market in coming years.

### 3.3.5 Security Perspectives

Energy security means different things to different countries resulting in policies that reflect a particular view (Aspen 2006; Dorian et al. 2006; Yergin 2006). Different national perspectives of energy security are the basis for potential conflict over energy resources. Russia, for example, aims to reassert state control over “strategic resources” and gain primacy over pipelines and market channels through which its supplies are transported into international markets (Yergin 2006). For energy importing countries such as Japan, energy security means offsetting scarce domestic resources through diversification, investment and trade (Suzuki et al. 1998; Yergin 2006). In Europe, the central debate is how to manage dependence on imported natural gas. And for most countries, aside from France and Finland the debate continues over the prospect of a nuclear energy revival and a return to coal. For the world’s only superpower, the United States, now faces the realization that its goal for “energy independence” is increasingly at odds with reality and that a new policy direction is inevitable. For developing nations such as China and India a primary concern is how changes in energy prices affect their balance of payments where energy security means rapidly adjusting to new dependence on global markets (Yergin 2006). The conventional energy security paradigm is based on differing national perspectives of what energy security means to each nation. In essence, this has been the root cause of geopolitical conflict and competition over energy resources. But factors that affect all nations such as fundamental changes in the energy demand and supply structure or the rising threats and vulnerabilities to conflict and climate change faced by all nations makes the need to shift from a national to global energy security perspective an imperative.

### 3.4 Converging Global Agendas: Energy Security, Climate Change & Sustainable Development

The original concept of energy security was so heavily influenced by fears of supply disruption that environmental concerns played only a minor role. There has now been a rethinking of the relationship between energy security and the environment. All the factors previously discussed including shifting demand and supply centres, rising vulnerability and threat, and heightened geopolitical tensions are producing a broader definition of energy security. The entry of phrases like “environmental security,” “resource conflict,” and “energy security” into the lexicon are examples of a changing dialogue. Rising fossil fuel dependence and the new climate change priority has made environmental considerations a

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64 A phrase made popular in the US after it was articulated by Richard Nixon four weeks after the 1973 oil embargo was put in place (Yergin 2006).
central part of the energy policy debate. As such, environment and sustainable development are becoming driving forces behind a new concept of energy security (Fesharaki 1999; Elhefnawy 2006).

The convergence of multiple and inter-related global scale agendas is among the most important feature of an energy security paradigm shift. Although some of the current energy security issues are reminiscent of the 1970s and 1980s, the energy security scene is markedly different today than in the past (Birol 2006; Kowalski 2006). Today, the energy security debate is joined by sustainable development, climate change and global poverty reduction (Brundtland 1987; UNFCCC 1992; MDG 2000). These international agendas combined with unrelenting economic growth in developing nations and a globalizing energy system represents a point in history without precedent. The International Energy Agency captures the urgency and dynamics of the current situation in the 2006 World Energy Outlook:

"The world is facing twin energy-related threats: that of not having adequate and secure supplies of energy at affordable prices and that of environmental harm caused by consuming too much of it. Soaring energy prices and recent geopolitical events have reminded us of the essential role affordable energy plays in economic growth and human development, and of the vulnerability of the global energy system to supply disruptions".

-IEA 2006a-

The international community has become more aware of the links between energy security, climate change, sustainable development and geopolitics implying an urgent need to address these issues in an integrated and coherent manner. Poverty, environmental deterioration and social, ethnic and political unrest can undermine global energy security. Increased understanding of these linkages implies that energy security issues cannot be separated from or resolved without addressing the broader economic, social, environmental and geopolitical issues (Abbot et al. 2006; IEA 2006a; Kowalski 2006; UNFCCC 2006).

In the future, among the central challenges that the world’s energy industry will face include: 1) growing oil scarcity, 2) meeting the needs of the developing world, 3) combating environmental degradation, and 4) achieving energy security (Dorian et al. 2006). Energy security, although the most poorly defined of the group has nonetheless commanded an immense amount of attention and resources throughout history and will continue do so in the future. The key energy security issues of today and the future were reflected by the G8 Summit leaders in 2006 listed in Table 3-6.

<table>
<thead>
<tr>
<th>Table 3-6. G8 Summit 2006: Key Energy Security Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>➤ High and volatile oil prices.</td>
</tr>
<tr>
<td>➤ Growing energy demand (estimated to rise by more than 50% by the year 2030, approximately 80% of which would still be met by fossil fuels, which are limited resources).</td>
</tr>
<tr>
<td>➤ Increasing import dependence in many countries.</td>
</tr>
<tr>
<td>➤ Enormous investment requirements along the entire energy chain.</td>
</tr>
<tr>
<td>➤ The need to protect the environment and to tackle climate change.</td>
</tr>
<tr>
<td>➤ Vulnerability of critical energy infrastructure.</td>
</tr>
<tr>
<td>➤ Political instability, natural disasters and other threats.</td>
</tr>
</tbody>
</table>

These challenges are global in nature and reflect a growing interdependence between producing, consuming and transitioning countries driven by a globalizing energy market. Currently, every day approximately 40 million barrels of oil crosses oceans on tankers. This figure could rise to 67 million by 2020 with both the U.S. and China importing 70% of their oil. The amount of LNG crossing the

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oceans will also rise to 460 million tons by 2020 representing a threefold increase from today (Yergin 2006). Energy security is, and will become increasingly a global agenda not a national interest. As a result, increased reliance between all stakeholders including governments, industry and international organizations will be a prerequisite for addressing the challenges.

The convergence of multiple global issues with the energy security agenda is further shown in a recent study conducted by the World Economic Forum65 (WEF 2006). A poll66 of 60 CEOs from global energy companies was taken to identify the most pressing issues of today. Figure 3-24 provides the results of the study. The horizontal axis shows how large an impact the issue is expected to have on the energy sector. The vertical axis indicates the degree of uncertainty surrounding an issue. The size of the bubble indicates the urgency of concern over time i.e. larger circles indicate immediate concern compared to smaller circles indicating issues that will become more important over the longer term.

Figure 3-24. World Economic Forum: Key Energy Security Issues of the Future


The results of the study reveal that energy security in the context of supply uncertainty in the Middle East, climate change and long-term energy supply are of the highest priority (WEF 2006). Although, a spectrum of other pressing issues are listed including terrorism, MDGs and China. The results of the poll were classified into the following categories: geopolitical/regional, policy/strategic, corporate ethics, global risks and vision issues. These categories are an indicator that the scope of energy security issues is broadening and becoming more complex. This is a fundamental shift in context from the energy security paradigm of the 1970s, which focused on oil supply as a national security interest, towards the present convergence of multiple global scale priorities. This is the strongest justification for the need to move away from the outdated, oil dependent energy security regime of the past. In other words, governments need to ask what energy security means today, and what implications will this have for tomorrow.

65 The World Economic Forum is non-profit organization founded in 1971 and based in Geneva Switzerland. It is well recognized as attracting some of the world’s most prominent industry and government leaders with far reaching influence in shaping global, regional and industry agendas (WEF 2006).

66 32/60 replied to the poll (53%) (WEF 2006).
Although the energy crises of past decades received great attention, environmental risk, post-Cold-War relations and poverty reduction are all important aspects of national and regional security. Most importantly, these issues are not independent of each other. There are strong links between energy security, environment, economy, geopolitics and poverty (Neff 1997; Feinstein 2002; Barnett 2002; Helm 2005; Abbott et al. 2006; UN 2006). For example, although energy is a driving force behind economic development and poverty reduction, it is also the cause of climate change, which in turn adversely impacts the health and livelihoods of the poor (Munasinghe 1999). These critical links are better understood with G8 Summit leaders acknowledging that neither global energy security, nor the Millennium Development Goals (MDGs) can be realized without sustainable access to fuels for 2.4 billion people, and electricity for the 1.6 billion people in developing countries (G8 2006).

The energy dimension of poverty can be characterized as the absence of sufficient choice in accessing adequate, affordable and reliable energy services to support economic and human development (Ceselski 2000). Empirical evidence for the link between lack of access to modern energy and poverty has become so convincing that international agencies including the United Nations Development Program (UNDP), World Bank, Asian Development Bank among many others are devoted to alleviating the problem (UNDP 2006; World Bank 2006; ADB 2006). Figure 3-25 is based on data from 100 developed and developing countries illustrating the relationship between per capita energy consumption and human development. UNDP’s Human Development Index (HDI) is used as a measure based on indicators of education level, life expectancy and per capita gross domestic product. The HDI provides a more balanced measure of human well being as opposed to the conventional use of Gross Domestic Product (GDP), which can marginalize the social and environmental dimensions of development.

![Figure 3-25. Relationship Between Per Capita Energy Consumption and Human Development Index (HDI)](image)

**Source:** UNDP 2004; IEA 2004

The results indicate that the HDI increases the most when energy consumption rises among countries whose per capita energy consumption is the lowest (<2 toe/capita). This suggests that a basic level of energy services can help the poorest segments of society the most. After 2 toe/capita has been reached

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67 Adult literacy and number of years of formal education.

68 Adjusted for purchasing power parity.

69 Tonnes Oil Equivalent.
there is a corresponding decrease in marginal benefits for human development. This parallels the
decoupling of GDP growth and energy consumption for countries\(^70\) passing a certain level of
industrialization\(^71\) (Goldemberg 1997; Chen et al. 2004). The important implication of the decoupling
of per capita energy consumption and human development is that it challenges the assumption that
human development is constrained by energy supply. For example, in low-income countries public
resources may be inadequate to finance energy investments for the poor because multiple programs
compete for limited funds (Feinstein 2002). However, from an energy security and sustainable
development perspective, relatively small investments to increase access to a basic level of energy
services could significantly benefit the most poor. Figure 3-26 illustrates the central role that energy
plays for sustainable development and poverty reduction in developing nations.

\[\text{Figure 3-26. The Role of Energy in Sustainable Development}\]

\[\text{Source: WEA 2004; Kanagawa & Nakata 2006}\]

Figure 3-26 shows how increasing access to modern energy in rural areas of developing countries
strongly contributes to the alleviation of time consuming labour and adverse impacts on health while
increasing education and income opportunities. In addition, access to modern energy can alleviate the
daily household burdens faced by many women and children in poor rural areas (WEA 2004; Modi et
al. 2005). Despite the tremendous gains in human development that could be made currently, more
than 1.6 billion people do not have access to electricity and are still dependent on traditional fuels

\(^70\) USA, Germany, UK, France, Japan, China, Poland (Goldemberg 1997; Takada et al. 2000).

\(^71\) Historical trends demonstrate rising energy intensity during early industrialisation followed by a decline after a
certain level is reached associated with improved energy conversion efficiency, improved processes, and a shift from
manufacturing to service sectors (Goldemberg et al. 1995; Takada et al. 2000).
limiting economic opportunity, education, health-care and communications. Figure 3-27 shows that a majority of these people live in South Asia and Sub-Saharan Africa (IEA 2004; WEA 2004; Birol 2006; IEA 2006).

![Global Energy Poverty Map]

**Figure 3-27. Global Energy Poverty**

*Source: IEA 2005*

Around 2.4 billion people still use fuel wood, charcoal, agricultural waste and animal dung to meet 90% of their daily energy needs for cooking and heating. The use of traditional biomass can have significant health implications due to inefficient combustion releasing high levels of indoor emissions into poorly ventilated receiving environments. Shockingly, about 1.3 million people, mostly women and children die prematurely each year because of exposure to indoor air pollution (WEA 2004). With a world population expected to reach 8 billion by 2030, increasing energy availability to the poor is critical for maintaining economic growth, jobs, and health care to an aging population. Without major government incentives, roughly 1.4 billion or 18% of the world’s population are still expected to be without power in 2030, despite global economic expansion and advances in energy technologies (Dorian et al. 2006).

Most importantly, there is evidence that in countries where local prices have adjusted to high international energy prices, due to the global energy insecurity that currently prevails, the shift to cleaner, more efficient ways of cooking has actually slowed and even reversed (World Bank 2006). Developing countries heavily dependent on imported energy can experience reduced terms-of-trade causing a fall in real national income. Consequently, the poor are usually the most vulnerable to the shocks provoked by energy market instabilities because energy already accounts for a high share of their meagre cash income. Government social programs that benefit the poor also tend to be cut back in times of fiscal stress (Takeda et al. 2000; Feinstein 2002; Kowalski 2006). This is one of the direct negative implications that an oil dependent energy security system has for achieving the Millennium Development Goals, one of the most important global priorities today.

There are still 1.6 billion people in the world without electricity. To achieve the Millennium Development Goals, this figure needs to fall under one billion by 2015. The additional investment cost to achieve 100% electrification is 665 billion USD over three decades or, 22 billion USD per year.

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72 According to the IEA (2006) if current trends persist the number of people using biomass is expected to increase to 2.6 billion by 2015 and to 2.7 billion by 2030 as populations grow. This means one-third of the world’s population may still be relying on traditional fuels, a share barely smaller than today.
representing a 7% investment increase for the electricity sector (IEA 2006a). If this figure appears large, consider the National Defence Council Foundation (Copolus 2003) estimate of 137.8 billion USD per year to protect oil supply in the Persian Gulf or the 2 trillion USD price tag for the Iraq War (Bilmes & Stiglitz 2006).

From a macroeconomic perspective, there is a strong correlation between economic growth (measured by GDP) and per capita energy consumption (kilogram oil equivalent) shown in Figure 3-28. Results are based on 160 developing and industrialized countries. The reason for the observed correlation is that nearly all economic activity depends on a reliable supply of energy. This in turn creates jobs and raises incomes (Feinstein 2002).

![Figure 3-28. Correlation Between Energy Consumption & GDP](image)

*Source: Modi et al. 2005*

Energy consumption and GHG emissions are also strongly correlated, implying a strong correlation between economic development and GHG emissions (IPCC 2001). This has significant implications from an energy security and climate change perspective because the strongest economic growth is occurring in developing nations fuelled by intense demand for oil and coal, the largest CO₂ emitters (Figure 3-29).

![Figure 3-29. World Energy Related CO₂ Emissions by Fuel](image)

*Source: IEA 2004*
From a global energy security perspective, rising oil demand in developing nations is straining a tight supply situation placing upward pressure on oil prices. High oil prices negatively feedback upon developing nations the most because their economies are less able to absorb price shocks. From a climate change perspective, due to oil dependent economic growth developing nations are projected to surpass OECD countries in total energy related CO$_2$ emissions around 2025 (Figure 3-30) (IEA 2004, 2006a).

![Figure 3-30. World Energy-Related CO$_2$ Emissions by Region](image)

*Source: IEA 2004, 2006a*

Developing countries are expected to account for over three-quarters of the increase in global CO$_2$ emissions between 2004 and 2030 overtaking the OECD as the biggest emitter (IEA 2006a). The share of developing countries in world emissions rises from 39% in 2004 to over 50% by 2030. This increase is faster than their share in energy demand, because their incremental energy use is more carbon-intensive than OECD and transition economies. Most importantly, the potential impact of climate change threatens developing countries the most. For example, changes in temperature could have a devastating impact on agricultural output reducing food security. Changes in precipitation patterns can also adversely affect the availability and quality of water, especially in areas where scarcity is already a problem, or rising sea levels could displace millions of people in densely populated coastal areas (IPCC 2007). What this demonstrates is that climate change, energy security and sustainable development are inextricably linked (Feinstein 2002).

Most troubling is the fact that although the greatest impacts of climate change will fall upon developing nations, OECD countries by far are responsible for the largest share on a per capita basis of energy related emissions (Figure 3-31).

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73 Carbon dioxide is the most important anthropogenic greenhouse gas. The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005. The atmospheric concentration of carbon dioxide in 2005 exceeds by far the natural range over the last 650000 years (180 to 300 ppm) determined from ice cores. The annual carbon dioxide concentration growth-rate was larger during the last 10 years (1995 – 2005 average: 1.9 ppm per year) than it has been since the beginning of continuous direct atmospheric measurements (1960–2005 average: 1.4 ppm per year) (IPCC 2007a).
Industrialized nations on a per capita basis will release more than four times the amount of CO\textsubscript{2} energy related emissions as developing nations by 2030. This results from the vast disparity in per capita energy consumption between developing nations and the industrialized world. Figure 3-32 shows by 2030, per capita primary energy consumption will average a mere 1.2 toe in developing regions compared with 5.4 toe in the OECD and 4.7 toe in transition economies (IEA 2004).

The vast disparity in energy consumption and related energy emissions on a per capita basis between developing countries and the industrialized world needs to be considered in the context of the current energy security paradigm, where resources that could be used to increase access to modern energy for the poor thereby, reducing poverty and GHG emissions are used instead, to maintain global oil dependency ultimately jeopardizing global energy security and sustainability. Energy security concerns
must extend far beyond the traditional view of oil supply security. Energy consumption now accounts for approximately 80% of global greenhouse gas (GHGs) emissions (Birol 2006). According to the Intergovernmental Panel on Climate Change (IPCC 2006), GHG emissions have increased the global mean surface temperature by 0.6 degrees. If current energy consumption trends persist, projections indicate an increase between 1.4 and 5.8 degrees by the end of the century having severe consequences upon economies and ecosystems for all regions of the world (EC 2006; IPCC 2006).

From a geopolitical perspective, environmental concerns and energy security fears can synergistically strain the international political system. The potential benefits of multilateral cooperation between the West and the developing world in forging joint solutions to energy supply and environmental challenges are compelling. The potentially steep costs of confrontation over energy supplies and environmental degradation are prompting some Asian nations to develop more energy-efficient technologies and alternative forms of energy. However, in the near term the likely move will be to diversify primary energy supply and the sources from which supplies originate. Nevertheless, there is tremendous potential for increased engagement between western countries and the developing world to enhance cooperation and develop new energy-efficient technologies and cleaner, alternative fuels to ensure peace and stability on the world stage (Jaffe 2004).

Among the world’s foremost challenges are mitigating the threat of climate change while addressing the rise of fossil fuel consumption. As a result, global energy security means reducing fossil fuel energy intensive economic growth, increasing access to modern fuels for the poor and reducing per capita energy consumption in the industrialized world. The geopolitical implications of a global threat such as climate change is evident. The world’s leaders need to move beyond the nationally bound perspective of an oil dependent energy security paradigm towards a global energy system that inherently considers how poverty, development, climate change and political relations are all closely linked.
4 EVOLVING A CONCEPTUAL FRAMEWORK FOR SUSTAINABLE ENERGY SECURITY

4.1 Challenges

Analysis of the origins and current implications of the conventional energy security paradigm revealed it to be deeply flawed. Energy security has at its roots both a military and economic foundation. The modern energy security system and the policies that followed arose in response to the oil shocks of the 1970s. This has led to an unrelenting focus on securing fossil fuels, particularly oil supply from key producing areas, most importantly the Middle East region that holds two-thirds of global oil reserves. A heightened sense of vulnerability from the industrialized world due to oil dependency has led to military projection in key producing areas around the world. The use of military force to “stabilize” oil-producing regions is viewed to be a legitimate extension of energy security policies. This is premised on the argument of protecting industrialized economies against oil market volatility arising from political instability within oil producing regions. These assumptions have been challenged by a review of empirical data that suggests making a definitive link between oil market volatility, political events and macro-economic effects upon the industrialized world is far from conclusive. In fact, the data suggests that a confluence of inter-related factors have led to the recent increase in oil prices, there is great uncertainty surrounding the precise dynamics, pathways and effects of oil shocks upon the macro economy and the market has a great deal of potential to mitigate the effects of oil supply and price disruptions. This calls into question the use of military force as a legitimate extension of energy security policies, and more importantly reveals how fundamentally flawed a modern energy security paradigm based on oil dependency is.

In past decades, a system of spare production capacity maintained by core producers paired with strategic oil stock releases appeared to be an effective solution to a physical oil supply shortage (WEA 2004). In recent years however, the tight balance between oil supply and demand has weakened both pillars of the conventional energy security system: First, the ability to respond to supply interruptions with surge production from Saudi Arabia, and second, the system of emergency oil stocks held by IEA countries has been weakened by the rise of non-member countries such as China and India that have a significant impact on world oil markets (Giusti 2005). Despite the increased efficiency of the market, energy import dependence from a single region or oligopolistic supplier will remain an energy security risk. As fewer countries continue to have capacity to export conventional oil, and global oil demand continues to rise, the potential for conventional oil supply disruption will grow (WEA 2004).

An oil dependent energy security system also places disproportionate impacts upon low-income nations. Increased vulnerability to energy markets and climate change directly contravenes poverty reduction programs. The three global priorities of climate mitigation, energy security and poverty reduction are inextricably interlinked reflecting a fundamental shift in the modern energy security paradigm which can be characterized as follows: 1) a shift in demand and supply centres away from the OECD towards developing nations, 2) the heightened level of vulnerability from terrorism and other threats upon critical energy infrastructure and market volatility driven by fear of stringent energy supplies; 3) rising geopolitical tension as existing powers and emerging economies compete over less available and concentrated resources; and, 4) the convergence of new global priorities such as the imperative for sustainable development and the overarching threat of climate change. These fundamental changes are placing immense stress upon the global energy system forcing a reconceptualization of what energy security means for the 21st century. An energy security system based on fossil fuel dependency is already the cause of sustained human conflict. This in combination with the direct contribution to climate change calls for a fundamental shift away from fossil fuel dependency towards a sustainable energy system. The energy security paradigm must evolve to engender the development of energy security policies that respond to these challenges.
4.2 Responding to the Challenge: A Conceptual Framework for Sustainable Energy Security Strategies

Energy systems must move towards sustainability worldwide. Energy Security is an essential component of the global energy system and should therefore remain consistent with the principles of sustainability. Figure 4-3 illustrates a conceptual framework of how energy security policies can remain consistent with the principles, measures and commitments to achieve global sustainability. The largest domain indicates the guiding principles or values that form the basis for action; the second domain are ecological and socioeconomic upper bound limits or thresholds that should not be compromised if sustainability is to be realized; the third domain are the political declarations and international commitments that are well established; and finally, the last domain are energy security strategies that should conform to, and reflect all other domains if they are to be sustainable.

The conceptual framework is illustrated as spherical domains that are embedded within each other. This is not meant to imply a hierarchy or a prioritization of activity, but that each domain interacts within the other. The illustrative size of each domain merely represents a conceptual scale of activity. For example, the assumption is that principles and values will underlie all subsequent activities and is therefore shown as the overarching domain; physical and socioeconomic boundaries are likely to be the next reference point that governs activity (although it could be argued that physical boundaries should be the overarching domain) and third, political commitments and declarations will reflect human principles and values and are implemented within biophysical and socioeconomic boundaries. It is proposed that sustainable energy security strategies should be conceived as being embedded within each of these domains and should therefore reflect the principles and measures within each domain in order to remain consistent with sustainability.

![Conceptual Framework for Sustainable Energy Security Strategies](image-url)
4.2.1 Guiding Principles & Concepts

The concept of sustainable development refers to development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987). This has social, economic, and environmental dimensions where the way energy is used and produced plays a fundamental role in either contributing to or, constraining the goal of sustainability. A sustainable energy system is one that does not compromise the prospects of current and future generations. Since the Rio Declaration of 1992, sustainability has evolved into a broad consensus and can be applied to energy as follows:

- Energy policy must seek to sufficiently supply the basic energy service needs of a growing world population and future generations.
- Equal opportunities to access basic energy services must be guaranteed for all members of society.
- Environmental burdens arising from the production and consumption of energy must be limited to a level that ensures the sustained life-support functions of the natural environment and human populations (Fritsche & Matthes 2003).

What these principles imply is that the major global challenges related to the energy system must be addressed including: 1) a secure supply of energy for economic growth and sustainable development worldwide, 2) providing electricity to the two billion people without access, 3) providing clean burning fuels for the two billion people currently relying on traditional fuels, 4) alleviating the burden of more than a hundred million women spending hours a day carrying fuel and water, and 5) mitigating environmental challenges, including indoor air pollution, urban air pollution, acidification, and climate change (Johansson 2001; WEA 2004).

In order to protect the natural life-support systems on which humanity depends, and to eradicate energy poverty in developing countries nothing less than a fundamental transformation of the global energy systems is required. A crucial aspect of this reconfiguration is the promotion of global peace by reducing dependency upon regionally concentrated oil reserves and ultimately shifting away from a fossil based society (WBGU 2004). What this implies is that in the context of energy security the fourth dimension of geopolitics needs to be added to the original three dimensions of sustainability (Figure 4-2). Most importantly each dimension is interlinked with the other where actions in one sphere will have direct and indirect repercussions for the other. Evidence for the interlinkages between these dimensions are seen by the convergence of climate change, sustainable development and energy security discussed in Section 3.4. What this implies is that integrated strategies that account for each sphere of activity will need to be taken in order to achieve a sustainable energy security system.
Upperbound limits are biophysical and socioeconomic criteria used to guide and inform the development of energy security policies. They are both qualitative and quantitative measures based on a composite between the concept of “guardrails,” developed by the German Advisory Council on Global Change (WBGU 1998, 2004) and supplemented by indicators for sustainable energy development developed by the International Atomic Energy Agency (IAEA 2005). They are complimentary because both are specifically designed to account for the sustainability aspects of energy systems from a macro perspective. Where they differ, is that guardrails act as goals – or minimum requirements depending on the perspective taken – to achieve a sustainable energy system; whereas, the sustainable energy indicators characterize in quantitative terms the current state of economic, environmental and social conditions in relation to energy production and use. Guardrails therefore include a time dimension by setting an intended future benchmark, whereas sustainable energy indicators reflect a current situation, although in principle could be used to benchmark future targets as well. The two central advantages of combining guardrails and energy indicators is that 1) they address different aspects of the same criterion in relation to the energy system. For example, the sustainable land use guardrail is concerned with protecting an absolute surface area of land to ensure food productivity, whereas the energy indicators measure the effects of energy development on soil quality, or the rate of deforestation attributed to energy use. The two clearly compliment each other when brought to bear upon the total implications of energy system development upon land use issues; and, 2) when brought together they address the current situation as well as setting future targets or requirements. This is particularly important since the development of energy security policies will almost always have to weigh between the short and long-term costs and benefits of a particular decision.

The WBGU (2004) defines guardrails as, “those levels of damage which can only be crossed at intolerable cost, so that even short-term utility gains cannot compensate for such damage”. For example, if in the interests of short-term economic gains the energy sector does not shift towards a more sustainable path, the costs of inaction will be higher over the long-term due to economic and social upheaval (WBGU 2004). In other words, as nations and regions pursue secure supplies of

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74 An international initiative to define Energy Indicators for Sustainable Development (EISD) led by led by the International Atomic Energy Agency (IAEA) in cooperation with the United Nations Department of Economic and Social Affairs (UNDESA), the International Energy Agency (IEA), Eurostat and the European Environment Agency (EEA).
affordable energy to fuel economic growth, short-term gains must be weighed against the long-term costs of pursuing unsustainable energy paths. The WBGU (2004) further indicates that guardrails should be considered minimum requirements to achieve a sustainable energy system. Given that sustainability will not always be the highest priority in the geopolitical pursuit of energy security, the minimum requirements to achieve a sustainable energy system could then be considered the upperbound limits that should not be crossed if an unsustainable path is pursued. The perspective of a minimum requirement is therefore reversed to represent a maximum limit accounting for those groups that may place short-term economic interests over longer-term sustainability.

The Upperbound Limit therefore serves a dual purpose; if a sustainable energy security path is chosen it can be viewed as a target to reach or, to benchmark progress; if a conventional energy security path is taken than it indicates a line that should not be crossed (Figure 4-4). For instance, consider the WBGU climate change guardrail where a surface temperature warming rate of 0.2°C per decade should not be exceeded. If a sustainable energy security path is chosen, strategies would be taken such as rapid uptake of renewables to reduce the rate of mean surface global temperature warming below 0.2°C per decade. The guardrail and indicators (e.g. GHG emissions from energy production and use per capita and per unit of GDP) would assist in benchmarking progress. If on the other hand, a conventional energy security strategy is taken such as expanding strategic oil stocks to protect against supply disruption, than in no way should doing so compromise the upperbound limit of surpassing a 0.2°C rate of global warming per decade. The same metric and indicators are used but for entirely different purposes. The upperbound limit is therefore a practical way of accounting for different levels of willingness to integrate sustainability into energy security strategies, where the former implies a high level of commitment and the latter implies a low level of commitment but, nonetheless sets boundaries to protect against complete negligence towards sustainability.

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**Figure 4-3. Dual Function of Upperbound Limits as a Benchmark for Sustainable Energy Security Strategies or a Warning Signal for Conventional Energy Security Strategies**
To supplement the WBGU guardrails, indicators for sustainable energy development developed by the International Atomic Energy Agency are used. These indicators were formulated to measure a country’s state of energy development and monitor progress towards sustainability. Most importantly, indicators can assist in understanding the implications of selected energy, environmental and economic programmes, policies and plans, and their impacts on shaping development. For energy security policies, when choosing energy fuels and associated technologies for the production, delivery and use of energy services, it is essential to account for economic, social and environmental consequences. Indicators can therefore assist in assessing the current and future effects of energy use on human health, society and the natural environment (IAEA 2005). Along with providing quantitative measures, indicators can give insight into key issues and how they relate to each other such as the positive relationship between access to modern cooking fuels and lower birth rates in poor rural areas (Goldemberg & Johansson 2002). As a result, if used effectively, indicators can move beyond just providing raw statistical data that may overlook site-specific context and dynamic interrelationships. Table 4-1 summarizes the WBGU guardrails and IAEA indicators when combined form the upperbound limits of the sustainable energy security framework to guide policy development. Note that IAEA indicators are not always directly related to the guardrails but characterize a different aspect of the same ecological or socioeconomic condition. The guardrails are already a type of indicator, but when combined with the IAEA indicators can provide a more complete picture of a given ecological or socioeconomic condition. IAEA indicators that could be applied to the conventional focus on security of energy supply are also listed at the bottom of Table 4-1.

Table 4-1. Summary Table of Upperbound Limits for Sustainable Energy Security Strategies

<table>
<thead>
<tr>
<th>WBGU Guardrails</th>
<th>IAEA Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Climate Protection</strong></td>
<td><strong>ENV1-GHG emissions from energy production and use per capita and per unit of GDP</strong></td>
</tr>
<tr>
<td>A rate of temperature change exceeding 0.2°C per decade and a mean global temperature rise of more than 2°C relative to pre-industrial levels should not be surpassed.</td>
<td></td>
</tr>
<tr>
<td><strong>Sustainable Land Use</strong></td>
<td><strong>ENV5-Soil area where acidification exceeds critical load</strong></td>
</tr>
<tr>
<td>10–20% of the global land surface should be reserved for nature conservation.</td>
<td><strong>ENV6-Rate of deforestation attributed to energy use</strong></td>
</tr>
<tr>
<td>Not more than 3% used for bioenergy crops or terrestrial CO₂ sequestration.</td>
<td><strong>ENV7-Ratio of solid waste generation to units of energy produced</strong></td>
</tr>
<tr>
<td>Natural ecosystems should not be converted to bioenergy cultivation.</td>
<td><strong>ENV8-Ratio of solid waste properly disposed of to total generated solid waste</strong></td>
</tr>
<tr>
<td>Where conflicts arise between different types of land use, food security should have priority.</td>
<td><strong>ENV9-Ratio of solid radioactive waste to units of energy produced</strong></td>
</tr>
<tr>
<td></td>
<td><strong>ENV10-Ratio of solid radioactive waste awaiting disposal to total generated solid radioactive waste</strong></td>
</tr>
</tbody>
</table>

Population growth tends to increase energy demand, but the availability of energy services can lower birth rates by shifting the relative benefits and costs of fertility towards a lower number of desired births in a family. Low-cost energy services can help accelerate a demographic transition to low mortality and low fertility by improving the local environment, educating women, and ameliorating the extreme poverty that may make child labour a necessity (Goldemberg & Johansson 2004).
<table>
<thead>
<tr>
<th>Protection of rivers and catchments areas</th>
<th>WBGU Guardrails</th>
<th>IAEA Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protection of marine ecosystems</td>
<td>The use of oceans to sequester carbon is not tolerable, because knowledge of ecological damage is insufficient.</td>
<td>ENV4-Contaminant discharges in liquid effluents from energy systems including oil discharges</td>
</tr>
<tr>
<td>Prevention of atmospheric air pollution</td>
<td>A preliminary quantitative guardrail is that pollution levels should nowhere be higher than current levels in the European Union (although the situation there is not satisfactory for all types of pollutants). A final guardrail would need to be defined and implemented by national environmental standards and multilateral environmental agreements.</td>
<td>ENV2-Ambient concentrations of air pollutants in urban areas ENV3-Air pollutant emissions from energy systems</td>
</tr>
<tr>
<td>Access to advanced energy for all</td>
<td>Ensuring access to electricity and substituting health-endangering biomass use by advanced fuels. Meeting the individual minimum requirement for advanced energy. The following final energy quantities should be the minimum requirement for elementary individual needs: By the year 2020 everyone should have at least 500 kWh final energy per person and year and by 2050 at least 700 kWh. By 2100 the level should reach 1000 kWh.</td>
<td>SOC1-Share of households or population without electricity or commercial energy or heavily dependent on non-commercial energy ECO1-Energy use per capita SOC3-Household energy use for each income group and corresponding fuel mix</td>
</tr>
<tr>
<td>Limiting the proportion of income expended for energy</td>
<td>Poor households should not need to spend more than 1/10 of their income to meet elementary individual energy requirements. Minimum macroeconomic development to meet the minimum per-capita energy requirement (for energy services utilized indirectly) all countries should be able to deploy a per-capita gross domestic product of about 3000 (USD in 1999)</td>
<td>SOC2-Share of household income spent on fuel and electricity ECO2-Energy use per unit of GDP ECO14-End-use energy prices by fuel and by sector ECO3-Efficiency of energy conversion and distribution ECO4-Reserves-to-production ratio ECO5-Resources-to-production ratio ECO6-Industrial energy intensities ECO7-Agricultural energy intensities ECO8-Commercial energy intensities ECO9-Household energy intestates ECO10-Transport energy intensities</td>
</tr>
<tr>
<td>Keeping risks within an acceptable range</td>
<td>WBGU Guardrails</td>
<td>IAEA Indicators</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>-----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Energy technologies should operate within the ‘normal range’ of environmental risk. Nuclear energy fails to meet this requirement because of its intolerable accident risks, unresolved waste management and the risks of proliferation and terrorism.</td>
<td>SOC4-Accident fatalities per energy produced by fuel chain</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Preventing disease caused by energy use</th>
<th>The overall health impact caused by indoor air pollution from biomass combustion and air pollution in towns and cities from fossil fuel combustion should not exceed 0.5% of total health impact in each region (for WHO regions measured in DALYs – disability adjusted life years).</th>
<th>ENV2-Ambient concentrations of air pollutants in energy systems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Energy Security Indicators:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECO11-Fuel shares in energy and electricity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECO12-Non-carbon energy share in energy and electricity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECO13-Renewable energy share in energy and electricity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECO15-Net energy import dependency</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECO16-Stocks of critical fuels per corresponding fuel consumption</td>
<td></td>
</tr>
</tbody>
</table>

Source: Adapted from WBGU 2004; IAEA 2005

### 4.2.2.1 Summary of WBGU Guardrails

**Climate Protection**

The rate of temperature change cannot exceed 0.2°C per decade and a mean global temperature rise of more than 2°C relative to pre-industrial levels therefore remaining within tolerable parameters for global climate change. Exceeding this level may cause fundamental changes to the natural system with profound affects upon human populations. From a warming level of 3.5–4°C onwards, adverse effects are expected for anthropogenic ecosystems in most regions of the world (IPCC 2001).
The climate protection window shows the tolerable rate of warming as a function of the absolute warming level already reached. The acceptable rate of change drops with increasing proximity to the maximum warming level of 2°C relative to pre-industrial levels (WBGU 2004).

**Sustainable Land Use**

The WBGU indicates that 10–20% of the global land surface should be reserved for nature conservation and not more than 3% used for bioenergy crops or terrestrial CO$_2$ sequestration. As a matter of principle, natural ecosystems should not be converted to bioenergy cultivation and if conflicts arise between different types of land use, food security should have priority. The WBGU (2001) has completed a first-order calculation of how sustainable use of the biosphere can be ensured for present and future generations indicating that a global network of protected areas should safeguard 10–20% of the worldwide terrestrial biosphere. This network can be established by differentiating according to biomes, countries, regions, etc., As a result, there can be regions where a larger conservation area percentage is appropriate while for other regions 2–5% may suffice.

The WBGU (2004) recommends allocating at most 3% of the terrestrial area to bioenergy crops yielding 45 EJ of primary energy. A detailed examination of individual continents would be required to avoid land-use conflicts with food and timber production, and conservation of natural ecosystems. Table 4-2 lists the WBGU’s proposals for regional guardrails. The energy quantity is calculated from a mean yield of 6.5 t/ha/y and a calorific value biomass of 17.6 MJ/kg. The percentages relate to total areas of continents. A precondition to their implementation is that the required worldwide-protected area network has been established beforehand (WBGU 2001).
Table 4-2. Regional Distribution of Potential Area for Energy Crops and Annual Quantity of Energy Produced From These Areas

<table>
<thead>
<tr>
<th>Region</th>
<th>Potential Area</th>
<th>Source</th>
<th>WBGU guardrails</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Million ha</td>
<td>%</td>
<td>Million ha</td>
</tr>
<tr>
<td>Europe</td>
<td>22</td>
<td>4.5</td>
<td>22</td>
</tr>
<tr>
<td>Asia &amp; Australia</td>
<td>37</td>
<td>0.7</td>
<td>29</td>
</tr>
<tr>
<td>Africa</td>
<td>111</td>
<td>3.8</td>
<td>111</td>
</tr>
<tr>
<td>Latin America</td>
<td>323</td>
<td>16</td>
<td>165</td>
</tr>
<tr>
<td>North America</td>
<td>101</td>
<td>5.9</td>
<td>67</td>
</tr>
<tr>
<td>World</td>
<td>595</td>
<td>4.6</td>
<td>394</td>
</tr>
</tbody>
</table>

Source: WBGU 2004

Assuming a global mean of 0.7t per hectare and year and a calorific value of 17.6 MJ per kilogram, a utilizable agricultural area of 1500 million hectares worldwide yields a potential of 18 EJ per year. Under European conditions, it is assumed that approximately 1.5t of forest timber can be used sustainably for energy purposes per hectare and year. Due to inaccessibility and conservation value of large parts of the boreal and tropical forests a global level of one-third of the European value is used i.e. to extract no more than 0.5t per hectare and year. A global forest area of 4170 million ha and a calorific value for wood of 18.6 MJ per kilogram results in a sustainable potential of 39 EJ per year. Thus, total cultivation of energy crops (45 EJ per year) including agricultural residues (18 EJ per year) and forestry residues (39 EJ per year) yields a sustainably utilizable potential of modern biomass of 100 EJ per year. A further 5–7 EJ per year is added from the traditional use of cattle dung to produce energy (WBGU 2004).

Protection of Rivers and Catchment Areas

Similarly to land use areas it is recommended that approximately 10–20% of riverine ecosystems including their catchment areas be conserved. In relation to the energy sector, hydropower dams can alter riverine ecosystems and displace human populations. Therefore, expansion of hydropower development needs to be limited. The existing international guidelines for sustainability (World Bank, OECD) should be applied to all hydraulic engineering projects. Implementation of the guidelines at the national level presupposes technical and institutional capacity-building as well as long-term responsibilities. If necessary framework conditions (i.e. investment in research, institutions, capacity building, etc.) are created over the next 10–20 years, an additional third of the presently utilized potential could be made accessible towards 2030 (power production totalling 12 EJ per year). If the above preconditions are met this amount could be raised to 15 EJ per year by 2100 (WBGU 2004).
Protection of Marine Ecosystems

It is recommended that the oceans not be used to sequester carbon because there is insufficient knowledge about the biological consequences. The marine biosphere is already impaired by conventional energy systems such as oil pollution and the warming of estuaries and coastal waters along with dumping of nuclear waste. Currently, two technology options are currently under debate for carbon storage in the oceans: Dissolution in seawater and storage in marine ecosystems. Deep-sea injection of carbon dioxide elevates the partial pressure of CO$_2$ while lowering the pH of seawater. There is inadequate scientific understanding of these biological affects. Similarly, there is insufficient understanding about the impacts of iron fertilization upon marine ecosystems. The precautionary principle should be applied and neither option is recommended for use within a sustainable energy system (WBGU 2004).

Wind power is renewable and in principle has low environmental impact. Offshore technology has also given wind power new potential for further development. However, large-scale offshore wind farms can impact the marine biosphere (e.g. in terms of bird conservation). Designated nature conservation areas should be excluded from offshore wind farm development, along with areas within the scope of the European Union Habitats Directive and bird breeding or, migration areas. Offshore wind power use can further compete with the demands of shipping, oil industry, fishery, nature conservation and other interests, which need to be reconciled when planning developments. The available data is not sufficient to define a global limitation for the development of offshore wind farms (WBGU 2004).

Prevention of Atmospheric Air Pollution

As a preliminary quantitative measure it is recommended that pollution levels should not surpass current levels in the European Union. This requires problematic assumptions, e.g. that the regional distribution of pollutants is similar, that pollutant imports and exports are negligible, and that ecosystem and soil types are all similarly sensitive. Regional standards could be set and implemented on the basis of the critical loads concept by adopting national environmental standards or multilateral environmental agreements. Critical loads and levels are science-based maximum limits for specific pollutants and receptors of varying sensitivity (ecosystems, sub-ecosystems, organisms). Critical loads are formulated at the receptor in an impact-related manner. They are determined numerically as the rate of deposition, which, if not exceeded is not, expected to damage receptors according to the current state of knowledge. Defining these limits is resource-intensive and complex requiring high-resolution spatial mapping of different receptors (e.g. ecosystem or soil types) and of pollutant loads for each individual pollutant. The Critical Loads concept is implemented in the 1979 Geneva Convention on Long-Range Transboundary Air Pollution but is limited to Europe and North America and therefore does not provide a basis for deriving a global maximum level (WBGU 2004).

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76 Carbon sequestration programs on land and in the oceans are gaining attention globally as a means to offset increasing fossil fuel emissions and atmospheric carbon dioxide concentrations. Many industrialized nations now have national plans to foster land-based sequestration. Ocean based sequestration, particularly deep ocean pumping of CO$_2$ and iron fertilization is also receiving attention, although it remains even more controversial than land-based programs. Despite uncertainties about the size and sustainability of sinks and markets, programs for emissions trading and carbon credits are underway, including the Chicago Climate Exchange and the European Union Greenhouse Gas Emission Trading Scheme (Chisholm et al. 2001; Lawrence 2002; Buesseler and Boyd 2003; Tsuda et al. 2003 in Jackson et al. 2007).
Access to Modern Energy

The World Energy Council (WEC) defines the provision of electricity to all households, which currently do not have access operationally feasible by 2020\(^\text{77}\) (WEC 2000). The following final energy quantities are recommended as minimum requirement for elementary individual needs: By the year 2020 at least 500 kWh final energy per person and year and by 2050 at least 700 kWh reaching 1000 kWh by 2100. A level of 450 to 500 kWh per person and year should be the absolute minimum, since this does not account for heating, transportation and supporting domestic and subsistence-economy activities. Technological advances in efficiency may meet the requirement with less primary energy. Table 4-3 lists minimum per capita final energy requirement where not achieving this level is viewed as non-sustainable. Calculations are based on a 5-person household.

Table 4-3. Minimum Per Capita Final Energy Requirement

<table>
<thead>
<tr>
<th>Energy Service</th>
<th>Explanations</th>
<th>Final energy requirement (kWh per person and year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potable water</td>
<td>Electric pump for 5 litres per person and day</td>
<td>2</td>
</tr>
<tr>
<td>Lighting</td>
<td>5 hrs per day with 20 W per household</td>
<td>7</td>
</tr>
<tr>
<td>Information and</td>
<td>Communication equipment (radio, TV, etc.) 5 hrs at 50W per household</td>
<td>18</td>
</tr>
<tr>
<td>communication</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refrigeration</td>
<td>0.4 kWh per day per household, primarily for food</td>
<td>29</td>
</tr>
<tr>
<td>Total interim</td>
<td></td>
<td>56 (electricity)</td>
</tr>
<tr>
<td>Cooking</td>
<td>1.5 cooked meals per day</td>
<td>400 (fuel)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>456</td>
</tr>
</tbody>
</table>

Source: G8 Renewable Energy Task Force 2001; WBGU 2004

Table 4-3 assumes efficient technologies are used in line with the current state of technology. Defining a minimum per capita energy requirement poses normative, methodological and technical problems. Among other things, climatic and geographical aspects must be taken into account, along with cultural, demographic and socio-economic factors. Furthermore, when converting energy services into energy amounts required, assumptions must be made about the technologies used.

The World Energy Council (WEC) estimates current electricity consumption by people in developing countries with access is on average 1300 kWh per person and year. In the lowest income quintile with access to electricity, the average is 340 kWh per person and year (WEC 2000). If more efficient technologies replace existing end-use devices electricity consumption could more than cover the minimum requirement.

Energy requirement for cooking and heating are viewed separately because electricity is typically not used. In developing countries, around 0.15 EJ from biomass is used for cooking (IEA 2001b; G8 Renewable Energy Task Force 2001). It is assumed that the per capita basic requirement is for 1.5 cooked meals per day on average. If highly efficient gas cookers are used 700–750 Wh per cooked meal is required amounting to 400 kWh per person and year.

Table 4-3 does not include space heating because the need for heating and the amount of energy used

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\(^{77}\) China’s success in connecting 6 million people in remote rural areas to the electricity grid each year demonstrates the potential for replication across the world, especially if stand-alone energy sources (e.g. village electricity supply systems) are established at first (WBGU 2004).
for this purpose depends on local climatic and building conditions which vary too much to define a meaningful average. Moreover, indoor heating is rarely required for the majority of countries with a low electrification rate and a high proportion of traditional biomass use. Mobility requirements are not included because no general assumptions can be made about the mode of transport (truck, ferry, bicycle, animal, etc.) (WBGU 2004).

**Limiting the Proportion of Income Expended for Energy**

It is recommended that poor households not spend more than one tenth of their income to meet basic individual energy requirements\(^78\) (500 kWh per person and year). Estimates for the share of disposable income spent on basic energy services by the poor in developing countries are 10% to 33% (ESMAP 1998, 1999; World Bank 2002a). Expenditure on energy for cooking is often not included in these estimates. If fuel is gathered at no cost, this expenditure may be very low in many rural areas but has high opportunity costs nonetheless, from time spent collecting fuel wood and damage to health. With 1.2 billion people living below the poverty line of 1 USD per day a 10% guardrail means that these people must be able to meet basic energy requirement at a cost of 37 USD per year. For a further 1.6 billion people who live on 1 to 2 USD a day, the tolerable amount ranges between 37 and 73 USD per year. On the assumption that income and income distribution remain constant and all of the 2.8 billion poorest people have a disposable annual income of 365 USD, the first 500 kWh per year should not cost them more than 7.3 US cents per kilowatt hour on average (electricity or fuel). The necessary cross subsidizing or social transfers (‘heating and electricity benefit’) decrease as the income of the poorest groups rises. Here, the income-generating effects of access to modern and affordable energy should act as an accelerator. It should be noted however, that electricity prices within a country may vary widely: In rural regions, where electricity is produced with diesel generators, the price is far higher than in the cities. Different subsidy practices further distort the values and therefore needs to be accounted for (WBGU 2004).

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\(^78\) This would be a significant improvement on the current situation in poor developing countries. Nonetheless, the proportion of income expended for energy would still be six times higher than in industrialized countries (WBGU 2004).
Minimum Macroeconomic Development

To meet a macroeconomic minimum per-capita energy requirement\(^{79}\) for energy services utilized indirectly, countries should achieve a per capita gross domestic product of 2900 – 3000 USD (1999). Total per capita energy requirements should include energy services used indirectly in the manufacture and distribution of all public and private goods, which the person consumes. This includes transportation services, which, for methodological reasons, were not accounted for when calculating individual energy requirements. The guardrail was determined as follows: Out of the 70 poorest countries, ten were identified which combine a relatively high value on the Human Development Index (HDI) and income-adjusted HDI with a low value on the Human Poverty Index (HPI) (Table 4-4). The ten countries selected have an adjusted HDI of 0.7–0.8 and an HPI of 11–29. Despite their relatively low GDP, they are countries which UNDP has classified as falling within the medium range of human development and are also included in the 50% of developing countries with an HPI lower than 30 (UNDP 2002a). They include Latin American and Asian but not African countries. The arithmetic mean of the ten countries’ annual per capita GDP is 2900 USD per person and year, which the WBGU considers to be the lower limit. Sixty countries with a total population of 2.2 billion did not achieve this threshold in 1999. In 21 countries with a total population of 375 million the indicator was below 1000 USD (WBGU 2004).

\(^{79}\) In principle, a macroeconomic minimum energy requirement per person and year can be derived from the primary energy consumption of the ten countries selected. If Jamaica is excluded due to high consumption, per capita consumption of commercial energy in the remaining nine countries is 4500 to 10500 kWh per person and year averaging 7500 kWh per person and year (Table 4-4) (WBGU 2004). Alternatively, the lower limit of 2900 USD per person and year could also be used directly to derive the economic minimum energy requirement. Taking mean primary energy required by all countries with a GDP between 2600 and 3200 USD per person and year to manufacture a product with a value of 1 USD in 1998 gives an economic minimum primary energy requirement of 7250 kWh per person and year. Reference could also be made to the average energy intensity of OECD countries (Table 4-4), which is 2.5 kWh per US dollar giving the same result. However, due to lack of available data this value does not fully reflect energy consumption from traditional biomass use, which has a significant role in almost all developing countries. Account for this will likely increase the average value by at least 1000 kWh per person and year. In view of the wide range of energy intensity, the difficulties associated with sectoral and geographical comparison between economies and variations in the amount of traditional energy used, the WBGU did not to set a quantitative guardrail for minimum energy consumption (WBGU 2004).

The WBGU tested from which point in time various scenarios enable an energy requirement of 7250 kWh per person and year to be achieved. Assuming an annual efficiency increase of 1.4% (to 2040) and 1.6% (from 2040) the threshold in 2020 would be around 5400 kWh per person and year, and in 2050 around 3500 kWh per person and year. However, due to the lack of available data the scenario was not tested. Based on this guardrail – and depending on increases in energy efficiency – with 7.6 billion people in 2020, a global primary energy consumption of 104–137 EJ is derived. Since 400 EJ are already used globally today and primary energy consumption will increase to 650 EJ by 2020 the guardrail is unlikely to pose any fundamental problems with the quantity of energy but with its distribution (WBGU 2004).
Table 4-4. Indicators of Selected Low-income Countries with Successes in Human Development and Poverty Avoidance (HDI-Human Development Index, HPI-Human Poverty Index, GDP-Gross Domestic Product) (average values calculated as an unweighted arithmetic mean)

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vietnam</td>
<td>1860</td>
<td>0.68</td>
<td>0.78</td>
<td>29.1</td>
<td>77.1</td>
<td>6044</td>
<td>2.9</td>
<td>37.8</td>
<td></td>
</tr>
<tr>
<td>Nicaragua</td>
<td>2279</td>
<td>0.64</td>
<td>0.69</td>
<td>23.3</td>
<td>4.9</td>
<td>6394</td>
<td>2.9</td>
<td>42.2</td>
<td></td>
</tr>
<tr>
<td>Honduras</td>
<td>2340</td>
<td>0.63</td>
<td>0.69</td>
<td>20.8</td>
<td>6.3</td>
<td>6171</td>
<td>2.6</td>
<td>54.8</td>
<td></td>
</tr>
<tr>
<td>Bolivia</td>
<td>2355</td>
<td>0.65</td>
<td>0.71</td>
<td>16.4</td>
<td>8.1</td>
<td>6354</td>
<td>3.0</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Indonesia</td>
<td>2857</td>
<td>0.68</td>
<td>0.74</td>
<td>21.3</td>
<td>209.3</td>
<td>8039</td>
<td>2.5</td>
<td>29.3</td>
<td></td>
</tr>
<tr>
<td>Ecuador</td>
<td>2994</td>
<td>0.73</td>
<td>0.81</td>
<td>16.8</td>
<td>12.4</td>
<td>8271</td>
<td>2.7</td>
<td>17.5</td>
<td></td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>3279</td>
<td>0.74</td>
<td>0.81</td>
<td>18.0</td>
<td>18.7</td>
<td>4478</td>
<td>1.5</td>
<td>46.5</td>
<td></td>
</tr>
<tr>
<td>Jamaica</td>
<td>3561</td>
<td>0.74</td>
<td>0.81</td>
<td>13.6</td>
<td>2.6</td>
<td>18003</td>
<td>5.3</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>3617</td>
<td>0.72</td>
<td>0.78</td>
<td>15.1</td>
<td>1264.8</td>
<td>10521</td>
<td>3.0</td>
<td>5.7</td>
<td></td>
</tr>
<tr>
<td>Guyana</td>
<td>3640</td>
<td>0.70</td>
<td>0.76</td>
<td>11.4</td>
<td>0.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>2878</td>
<td>0.69</td>
<td>0.76</td>
<td>18.6</td>
<td>8253</td>
<td>2.9</td>
<td>28.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Developing countries</td>
<td>3530</td>
<td>0.65</td>
<td>0.68</td>
<td>4609.8</td>
<td>2.7</td>
<td>16.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poland</td>
<td>8450</td>
<td>0.83</td>
<td>0.87</td>
<td>38.6</td>
<td>31564</td>
<td>3.6</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>16064</td>
<td>0.87</td>
<td>0.89</td>
<td>10</td>
<td>23792</td>
<td>1.7</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>23742</td>
<td>0.92</td>
<td>0.93</td>
<td>82</td>
<td>49080</td>
<td>2.1</td>
<td>1.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>31872</td>
<td>0.93</td>
<td>0.92</td>
<td>280.4</td>
<td>93682</td>
<td>3.0</td>
<td>3.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eastern Europe and CIS</td>
<td>6290</td>
<td>0.78</td>
<td>0.82</td>
<td>398.3</td>
<td>5.6</td>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OECD</td>
<td>22020</td>
<td>0.90</td>
<td>0.90</td>
<td>1122</td>
<td>2.5</td>
<td>3.3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: UNDP 2002a; World Bank 2002a in WBGU 2004

Keeping Risks Within a Normal Range

A sustainable energy system should build upon technologies where operation remains within a ‘normal range’ of environmental risk across the entire supply chain including various primary energy carriers to the end consumer and final waste. The ‘normal range’ – as opposed to transitional and prohibited ranges – is defined by the WBGU’s Report, ‘Strategies for Managing Global Environmental Risks’.

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80 Risks in the normal area have: 1) low uncertainties over the probability distribution of damage, 2) small catastrophic potential, 3) low to medium uncertainty about probability of occurrence and magnitude of damage, 4) low statistical confidence intervals for probability and magnitude of damage, 5) low levels of persistency and ubiquity (scope in time and space), 6) high reversibility of potential damage and 7) low potential for social conflict and mobilization. In this ‘normal’ case a simple link of probability and severity through multiplication of the two
In the production and transportation of fossil fuels and the operation of fossil-fuelled power stations accidents can occur due to error, sabotage or other risks. Such accidents have a limited impact in spatial and temporal terms and are therefore considered within the normal range of environmental risk (WBGU 1998). Other guardrails including climate protection and atmospheric air pollution prevention restrict the risk of emissions. Other renewable energy carriers including small-scale hydropower, wind, solar energy, biomass, geothermal energy, etc. are non-hazardous falling within the normal range of environmental risk. Currently, there is no guarantee over the safe operations of nuclear power plants, non-hazardous long-term storage of nuclear waste and non-proliferation of radioactive materials for terrorist purposes. The WBGU recommends abstaining from the use of nuclear power.\footnote{Nuclear energy is not recommended for a sustainable energy system because of its intolerable accident risks, unresolved waste management and the risks of proliferation and terrorism. The present use of nuclear energy (from uranium extraction to reprocessing) involves the release of radiation posing an environmental risk. There are two central types of risk with nuclear power: First, risks associated with normal operation and waste management, and second, risks associated with proliferation and terrorism. The risks associated with the normal operation of nuclear power plants fall within the borderline range of environmental risk (WBGU 2000). The WBGU also considers that the management of waste from the nuclear industry also falls within the borderline range. Due to unresolved problems the WBGU classifies both proliferation and nuclear terrorism in the low to medium probability range with the extent of damage being substantial. This falls between the borderline and prohibited ranges (WBGU 2000, 2004).}

Preventing Disease Caused by Energy Use

Indoor air pollution caused by the burning of biomass, and air pollution in towns and cities from fossil fuels causes severe health damage worldwide. The overall health impact from these energy uses should not exceed 0.5% of the total health impact in a region as measured in DALYs (disability adjusted life years). DALYs are used to formulate tolerable limits for health impairment (morbidity) caused by energy production and use. DALYs measure the burden of disease in populations by combining Years of Life Lost (YLLs) and Years Lived with Disability (YLDs). This indicator has been criticized due to its weighting of age and specific diseases, which can under, or overestimate certain health impacts (UNDP 2002b). Nonetheless, in the World Health Organization (WHO) World Health Report 2002, risk factors are attributed to health impacts quantifying the proportion of health damage caused in terms of DALYs. The approach is applies to urban and indoor air pollution (WHO 2002b).

Although it is difficult to establish clear causal chains between energy production and use and health damage there are two proven domains of impact on health. The first is local urban and indoor air pollution caused by fumes released during fossil fuel or biomass combustion. Urban air pollution causes almost half of the 7.9 million DALYs affecting the western Pacific region and South-East Asia (especially China) the most (Figure 4-6). In India, the health factors – probability and severity – are relatively small, then the product of the two falls in the normal area (WBGU 2000). No immediate action for normal risks is required other than proper management. When risks surpass normal levels the transitional area is reached if one or more of the following conditions are met: 1) damage potential is high, 2) probability of occurrence is high, 3) uncertainty of the probability distribution of adverse effects is high, 4) confidence intervals of probability and magnitude of damage are large, 5) persistency, ubiquity and irreversibility are high, whereby there must be reasonable grounds to assume a causal link between trigger and effects, and 6) where potential distributional injustice or other social and psychological factors, conflict or mobilization is expected (migration, refusal, protest, resistance). If one of these conditions is met, then the product of probability and severity will be in the transitional area. If the product of the two components of risk assumes extreme levels then risk falls in the prohibited area. In the prohibited area, risk reduction is unconditional where in extreme cases an immediate ban or moratorium is recommended (WBGU 2000).
impairment caused by indoor air pollution is greater than the effects of smoking or malaria. Values below 0.5% as a share of regional DALYs have been achieved for urban and indoor air pollution in much of the world. Nevertheless, the WBGU proposes that the share of regional DALYs caused by these two risk factors should be reduced below 0.5%\(^2\) (WBGU 2004). Figure 4-6 shows health impairment attributed to local air pollution. The proportion of DALYs in the specific subregion is used as an indicator. Values above 0.5% surpassing the guardrail is coloured black. Figure 4-6 a) shows health impairment caused by urban air pollution; and, b) shows health impairment caused by fumes in indoor areas.

![Map showing health impairment attributed to local air pollution using DALYs as an indicator.](image)

**Figure 4-5. Health Impairment Attributed to Local Air Pollution Using DALYs as an Indicator**

*Source: WHO 2002b in WBGU 2004*

### 4.2.3 International Commitments

Sustainable energy security policies must remain consistent with global priorities reflected in international commitments and political declarations established by the international community.

\(^{82}\) The WHO has drafted the ‘Air Quality Guidelines for Europe’ in 1987 and later extended them to the global level proposing guidelines and threshold values for air pollutants including ozone, carbon monoxide, volatile organic compounds, nitrogen oxides, sulphur oxides and suspended particulates, which may serve as a basis for formulating national standards (WBGU 2004).
These commitments address the role of energy in poverty reduction, sustainable development and climate protection. In the past, energy, climate change and development were pursued separately in policy and research\(^83\). International discussions for some time did not explicitly address the linkages between energy, climate, and development. For instance, development issues did not figure prominently into the global climate change debate for years, even though climate change had clear implications for development priorities such as poverty reduction and food security. Similarly, energy security issues were not included in climate change discussions. Conventionally, measures to control oil prices are taken with little regard for environmental concerns and when the UN Convention was framed in 1992 energy issues were not given high priority because the world had already adjusted to the energy crises of the 1970s (Beg et al. 2002 in Koakutsu & Watanabe 2006).

The international community is increasingly acknowledging the important intersections between various global priorities. This is particularly true since the Brundtland report of the World Commission on Environment and Development (1987) brought the concept of “sustainable development” to the forefront of global debate. Table 4-5 summarizes important political declarations, and international commitments that address the interlinkages between energy security, climate change and sustainable development.

**Table 4-5. Sample of International Agreements Linking Energy, Climate Change & Sustainable Development**

- Kyoto Protocol\(^84\), UNFCCC 1997.
- Millennium Declaration, UN General Assembly 2000.
- Johannesburg Plan of Implementation (JPOI), World Summit on Sustainable Development (WSSD) 2002.

In recent decades, progress has been made in addressing global energy issues at international conferences and in declarations and treaties. At the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro 1992, the international community committed itself for the first time to comprehensive targets for human development and environmental protection set out in

\(^{83}\) For a variety of reasons including differences in disciplines (e.g. natural vs. social sciences), temporal scale (i.e. climate change viewed over centuries as compared to development and energy issues viewed over decades), and geographic scope and data certainty (climate change covers global and regional scales with a degree of data uncertainty vs. development and energy at national and regional levels with a relatively higher degree of confidence in data) (Koakutsu & Watanabe 2006).

\(^{84}\) The Kyoto Protocol has committed signatories to reduce their greenhouse gas emissions by 5.2% from 1990 base levels by 2008-2012. This has resulted in adoption of regional and national reduction targets. In the European Union the commitment is to an overall reduction of 8%. In order to reach this target, the EU has agreed to increase its proportion of renewable energy from 6% to 12% by 2010. The Kyoto signatories are currently negotiating the second phase of the agreement, covering the period 2013-2017. Within this timeframe industrialised countries need to reduce their CO\(_2\) emissions by 18% from 1990 levels and 30% between 2018 and 2022 (EREC 2007).

\(^{85}\) The JPOI called for improved access to reliable and affordable energy services for rural development to help achieve the Millennium Development Goals (MDGs) (Koakutsu & Watanabe 2006).
Agenda 21 and the Rio Declaration. Although none of Agenda 21’s 40 chapters focuses explicitly on energy it is featured as a subsection of Chapter 9 (Protection of the atmosphere) and Chapter 14 (Promoting sustainable agriculture and rural development). In 1997, the Nineteenth Special Session of the United Nations General Assembly in New York (Earth Summit +5) identified the need to support developing countries in building a sustainable energy supply e.g. through technology transfer and development cooperation. The meeting urgently recommended the incorporation of external environmental costs into the pricing structure and the dismantling of subsidies on unsustainable energy carriers (WBGU 2004; Vera et al. 2005).

In preparation for the ninth session of the Commission on Sustainable Development (CSD) in New York, April 2001, for the first time, an intergovernmental process focusing on energy was created. The UN Commission on Sustainable Development (CSD) subsequently adopted a number of global energy policy recommendations in the publication Energy for Sustainable Development: A Policy Agenda86 (Goldemberg & Johansson 2002). Although, the United Nations General Assembly adopted the Millennium Development Goals (MDGs) in 2000, no explicit goal on energy was adopted. The ninth session of the Commission on Sustainable Development (CSD-9) in 2001 was an important landmark in the process leading to the World Summit on Sustainable Development (WSSD) in reaching a consensus that the current energy situation is not sustainable. The WSSD met in September 2002, and its Plan of Implementation made specific recommendations on energy access to facilitate the achievement of the Millennium Development Goals and established a clear link between energy and the eradication of poverty87 (WEA 2004).

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Box 7. Energy Charter Treaty

The Energy Charter Treaty (ECT) is the most significant international treaty dealing with cross-border cooperation among industrialized countries in the energy sector. The Treaty, which evolved from the 1991 European Energy Charter, came into force in 1998 with a protocol on energy efficiency and related environmental aspects. In 2007, 51 states have ratified the Treaty but several major states including Russia, Norway, Iceland, Belarus and Australia have not ratified and the United States and Canada have not signed the ECT. The aim of the ECT is to promote economic growth through the liberalization of investment and trade. To this end, it extends the GATT rules to the energy sector. Minimum standards for foreign investment and energy transport were agreed upon. Both these areas, as well as the issue of transit of energy products, are to be further developed on a binding basis. Environmental aspects of energy policy are framed in general terms and set out recommendations on energy efficiency, external costs, clean technologies and cooperation on environmental standards, etc. More detailed provisions are included in an additional environmental protocol, the Energy Charter Protocol on Energy Efficiency and Related Environmental Aspects (PEEREA), although this has no binding legal force (ECT 1991; WBGU 2004; WEA 2004).

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86 Including access to energy services, energy efficiency, renewables, next-generation fossil fuel technologies, nuclear power, rural energy systems, and transport. Research and development, capacity building, technology transfer, access to information, mobilization of financial resources, the removal of market distortions, and the inclusion of stakeholders were identified as cross-cutting measures (Goldemberg & Johansson 2002).

87 At the World Summit on Sustainable Development (WSSD) in 2002, energy was included as a separate agenda item for the first time focusing on renewables, access to energy services, organization of energy markets and energy efficiency. However, due to blocking tactics by an anti-target lobby comprised of USA, Australia and OPEC countries a target of at least 15% of global energy supply from renewables by 2010 was not adopted. For other targets, such as the removal of market distortions or increasing research and development in the field of energy efficiency – no success indicators or timeframes were adopted, nor were targets established on a legally binding basis. However, various initiatives were adopted, with states, corporations and NGOs pledging to cooperate. The EU established quantifiable, time bound targets for the development of renewables and pledged €700 million to improve access to reliable and affordable energies in the developing countries. UNEP launched the Global Network on Energy for Sustainable Development to promote ‘clean’ energy technologies in developing countries and Germany hosted the International Conference for Renewable Energies in June 2004 (WBGU 2004).
The 1991 Energy Treaty Charter (ETC) reflects an international commitment to energy security and highlights the need for interregional cooperation to enhance security of energy trade, transportation and infrastructure, and environment (Box 5). The international community has also made a commitment to global sustainability reflected both implicitly and explicitly in the various conventions and agreements. The imperative to mitigate climate change, assist developing countries in sustaining economic growth and eradicate poverty are the guiding principles that govern the implementation of the United Nations Framework Convention on Climate Change (Box 6) (UNFCCC 1992) and the Kyoto Protocol (1997). The Millennium Development Goals have also set concrete targets for reductions in poverty, improvements in health and education, and protection of the environment. These goals have been adopted by the World Bank Group (WBG), the International Monetary Fund (IMF), and the Development Assistance Committee of the Organisation for Economic Co-operation and Development (OECD), and many other agencies (Feinstein 2002). The international community has pledged to move towards global sustainability and has acknowledged the central role of energy. This commitment needs to be reflected in the development of energy security policies and strategies. As such, the energy security paradigm must now incorporate and account for the principles of sustainability that form the basis of these international commitments.

Box 8. The United Nations Framework Convention on Climate Change & The Kyoto Protocol

The United Nations Framework Convention on Climate Change (UNFCCC) defines objectives and principles, bodies and mechanisms for international climate protection policy. It entered into force in 1994 and has been ratified by 184 countries around the world. Climate policy entails a radical reduction in CO2 emissions worldwide achieved through restructuring of the global energy systems (Chapter 4). UNFCCC is the driving force and the most significant international forum where states discuss the interface between environmental and energy policy and adopt major decisions.

The Kyoto Protocol to the UNFCCC was adopted in 1997 by more than 160 nations. The Protocol sets out specific reduction commitments for a defined group of greenhouse gases committing industrialized countries to reduce greenhouse gas emissions by at least 5% between 2008–2012 against the baseline year of 1990. Annex I of the Protocol stipulates a precise reduction target for each industrialized country (EU 8%, USA 7%, Japan 6%, Australia +8% and Russia 0%). The developing countries have not undertaken specific reduction commitments pointing out that the main producers of climate change (i.e. the industrialized countries) should take the lead. The Protocol allows industrialized countries some flexibility in implementing their commitments through emissions trading where an industrialized country which exceeds its reduction target can sell its surplus emissions permits to countries which have difficulty meeting their targets. Industrialized countries can also earn credits by investing directly into emissions reduction projects in other developed countries that have taken on a Kyoto target (Joint Implementation, JI). The Clean Development Mechanism (CDM) is a way for industrialized countries to earn credits by investing in emissions reduction projects in developing countries.

It was not until the 7th Conference of the Parties (COP7) in 2001, building upon the 2000 Bonn Agreement, that a path was laid for the Kyoto Protocol’s rapid entry into force. The requirement for entry into force is ratification by 55 states representing at least 55% of the CO2 emissions in the 1990 baseline year. This means that entry into force is possible even without the USA and Australia, which have pulled out of the Kyoto process (UNFCCC 1992; Kyoto Protocol 1997; BGWU 2004).

88 Provisions referring to development and energy issues in the Convention include Preamble, Article 2, Article 3.4 and Article 4.1c; for the Protocol (Article 10 and Article 12.2) (UNFCCC 1992; Kyoto Protocol 1997).
4.2.4 Energy Security Strategies

Energy security strategies can be taken on the supply-side and demand-side. A third crucial strategy deals with geopolitical relations, which could be the determining factor for enhancing or reducing energy security. Nevertheless, a range of actions can be taken; on the supply-side central actions involve reducing fossil fuel import dependence and diversifying primary energy sources. The principle of diversification can also be applied to suppliers, technologies, transport routes and infrastructure based on the assumption that a distributed system is less vulnerable to large threats. On the demand side, improving energy efficiency and conservation is the central measure to reduce primary energy requirements. More conventional strategies include building up strategic oil reserves, accelerating exploration for new fossil reserves or, increasing infrastructure investments. And finally, due to a globalizing energy market and integrating supply chains, energy interdependence is a central feature of the global energy system. As such, a critical factor will be the geopolitical relations between nations as this can influence all other demand or supply-side strategies.

What the sustainable energy security framework implies is that all energy security strategies should account for each domain of sustainability within the framework including 1) international commitments and declarations, 2) ecological and socioeconomic upperbound limits and 3) the principles and values that govern all these activities. In doing so, the formulation of energy security strategies must recognize the direct links between meeting the needs of economic growth, improving the conditions for a better quality of life and ensuring sustainable development while protecting the environment (WEA 2004). The following section assesses both supply and demand-side strategies along with the geopolitical dimensions of energy security from a sustainability perspective.

4.3 Synthesis of Sustainable Energy Security Strategies

4.3.1 Supply Diversification

A key strategy for achieving a more reliable energy supply and secure energy infrastructure is through diversification. This concept was imported to some degree from ecology. Vulnerability due to a lack of diversity was demonstrated in the first oil crisis where price hikes in 1973 led to an active and successful search for oil reserves outside the Middle East and especially outside the Organization of Petroleum Exporting Countries (OPEC). The resulting diversity of supply reduced the power of OPEC as an oligopoly. However, non-OPEC production seems to be peaking, which has renewed concerns about the concentration of reserves in the Middle East, and oil supply vulnerabilities (Farrell et al. 2004). In the past 20 years, the emergence of gas has improved the supply mix. Italy for example, has reduced oil dependence by promoting gas. New member states on the other hand still rely heavily on coal and less on imported oil and gas. Different supply mix strategies are taken across regions of the world, which will depend on a variety of factors such as access to domestic resources. Table 4-6 provides comparative fuel type data for different countries and regions across the world. On average coal, oil, gas and nuclear contributes 15%, 43%, 24% and 13% respectively in the EU-15 and 18%, 40%, 24% and 13% respectively in the EU-25. In comparison, the energy mix in the US is 24%, 39%, 26% and 8% respectively, while its dependence on imports is 61% for oil, and 18% for gas.

Generally the security of supply risk is smaller in a more balanced energy mix because the origins of coal, oil, and gas are different. Nevertheless, the ability to switch fuels in consumption is limited. Therefore, promoting technologies with enhanced capabilities to switch at short notice between fuels can improve the energy security of countries. The viability of these technologies can be improved in some cases by allowing market forces to set the price of competing fuels (van der Linde et al. 2004; World Bank 2005).
Table 4-6. Regional and Country Comparative Data for Energy Consumption Per Fuel Type 2002 (Mtoe)

<table>
<thead>
<tr>
<th>Country</th>
<th>Oil</th>
<th>Gas</th>
<th>Coal</th>
<th>Nuclear</th>
<th>Renew.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>13.0</td>
<td>7.3</td>
<td>3.5</td>
<td>8.9</td>
<td>32.7</td>
<td>100%</td>
</tr>
<tr>
<td>Belg. &amp; Lux.</td>
<td>32.9</td>
<td>13.4</td>
<td>7.3</td>
<td>9.7</td>
<td>63.8</td>
<td>100%</td>
</tr>
<tr>
<td>Denmark</td>
<td>9.8</td>
<td>4.6</td>
<td>4.2</td>
<td>-</td>
<td>18.6</td>
<td>100%</td>
</tr>
<tr>
<td>Finland</td>
<td>10.9</td>
<td>3.7</td>
<td>4.5</td>
<td>5.1</td>
<td>26.6</td>
<td>100%</td>
</tr>
<tr>
<td>France</td>
<td>92.8</td>
<td>38.5</td>
<td>12.7</td>
<td>98.9</td>
<td>258.0</td>
<td>100%</td>
</tr>
<tr>
<td>Germany</td>
<td>127.2</td>
<td>74.3</td>
<td>84.6</td>
<td>37.3</td>
<td>329.4</td>
<td>100%</td>
</tr>
<tr>
<td>Greece</td>
<td>21.8</td>
<td>1.8</td>
<td>9.9</td>
<td>0.9</td>
<td>34.2</td>
<td>100%</td>
</tr>
<tr>
<td>Ireland</td>
<td>8.7</td>
<td>3.7</td>
<td>1.8</td>
<td>Na</td>
<td>14.4</td>
<td>100%</td>
</tr>
<tr>
<td>Italy</td>
<td>92.9</td>
<td>57.2</td>
<td>13.8</td>
<td>Na</td>
<td>174.8</td>
<td>100%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>43.8</td>
<td>35.4</td>
<td>8.9</td>
<td>9.1</td>
<td>89.0</td>
<td>100%</td>
</tr>
<tr>
<td>Portugal</td>
<td>14.9</td>
<td>2.7</td>
<td>5.0</td>
<td>Na</td>
<td>24.1</td>
<td>100%</td>
</tr>
<tr>
<td>Spain</td>
<td>73.5</td>
<td>18.8</td>
<td>21.9</td>
<td>14.3</td>
<td>134.5</td>
<td>100%</td>
</tr>
<tr>
<td>Sweden</td>
<td>15.0</td>
<td>0.7</td>
<td>2.2</td>
<td>15.6</td>
<td>48.5</td>
<td>100%</td>
</tr>
<tr>
<td>UK</td>
<td>77.2</td>
<td>85.1</td>
<td>36.5</td>
<td>22.0</td>
<td>220.3</td>
<td>100%</td>
</tr>
<tr>
<td>EU 15</td>
<td>634.4</td>
<td>347.2</td>
<td>216.8</td>
<td>201.7</td>
<td>1468.9</td>
<td>100%</td>
</tr>
<tr>
<td>EU 22</td>
<td>689.7</td>
<td>403.7</td>
<td>314.6</td>
<td>222.3</td>
<td>1706.2</td>
<td>100%</td>
</tr>
<tr>
<td>US</td>
<td>894.3</td>
<td>600.7</td>
<td>553.8</td>
<td>185.8</td>
<td>2293</td>
<td>100%</td>
</tr>
</tbody>
</table>


The two driving forces behind future supply diversification will be global reaction to the threat of climate change and a move away from oil where possible given its market volatility and long-term concerns over resource availability (World Bank 2005). The following are possible options to diversify fuel types:

Oil

Diversification of origin in oil has expanded in the last 20 years. The number of oil producing countries has increased where import dependency on OPEC imports was reduced by production in Norway and the UK. After the oil crises of the 1970s, oil imports from other regions was promoted. The rapid expansion of international oil trade has created more transparency, the ability to arbitrate prices in the international market and hedge price risks in various markets (van der Linde et al. 2004). Despite increased market efficiency, current trends indicate a growing concentration of oil reserves and future production centres in the Persian Gulf region. This combined with maturing oil production and a comparatively higher rate of total oil reserve declines in OECD countries will create significant future import dependency on fewer suppliers. This key feature of the current shift in the energy security paradigm needs to be considered in the context of a more sustainable strategy. The structural shifts in the global energy system including dwindling reserves, rising demand and increased risks due to rising dependency and concentrated supply centres reveals the inevitable limitations of a conventional energy security strategy that focuses on enhancing oil supply.
Gas

Environmental concerns and reduced costs of gas pipeline and LNG projects due to technological progress have increased the global penetration of natural gas (World Bank 2005). However, the potential to diversify gas by origin is more limited than for oil because gas supply routes are more rigid since most of it is transported through a fixed pipeline network. The other way to transport gas is by ship. The method and route of transport will be largely influenced by market and geopolitical factors such as transportation costs and political alliances (van der Linde et al. 2004; UNECE 2006). Policies that enhance gas’s competitive strengths against oil and coal in the context of environmental benefits could be part of a sustainable energy security strategy. Moreover, regionally integrated gas markets, for example, the EU and Russia provides an opportunity to develop regional cooperation in order to reduce the uncertainty and risks of long lead time capital intensive projects, facilitate cross border and third party trade and develop mutually beneficial supplier/consumer pricing arrangements (World Bank 2005).

Coal

With high natural gas prices and large supplies of coal in many countries, coal is re-emerging as a potentially reliable and cost-effective option. Coal has large and diversified reserves available from politically stable regions. Global infrastructure is also well developed where new supplies can be efficiently brought on stream. However, coal has one of the largest environmental footprints throughout the entire supply chain. Existing, commercially viable clean coal technologies can mitigate the environmental impact of coal use at all stages of the coal cycle. For instance, emerging new technologies (carbon capture and storage, gasification and liquefaction) are creating the potential for coal us in power generation with low or no emissions, and over the longer term possibly for transport. While the expected progress in clean coal technologies will increase coal’s environmental appeal, it will also increase capital and operating costs (van der Linde et al. 2004; World Bank 2005; UNECE 2006). Clean coal technologies that could contribute to enhancing energy security from a sustainability perspective have faced constraints in terms of competitiveness against other sources of energy. Industrialized countries can contribute to the penetration rate of clean coal technologies by supporting R&D to increase competitiveness, while in developing nations more achievable benefits may be gained through improved pricing mechanisms, more selective coal mining, or better coal preparation (World Bank 2005). In other words, coal could become a viable part of a sustainable energy security strategy if the environmental challenges can be dealt with cost-effectively.

Nuclear

Since the early 1980s, nuclear power plants have faced public opposition over the possible consequences of accidents, the lack of adequate methods for final waste disposal, the risk of nuclear weapon proliferation and the direct costs of construction, operations and decommissioning. There are signs of renewed interest in nuclear power, evidenced by Finland’s construction of a new nuclear power reactor, the United Kingdom’s decision to potentially resume construction of new nuclear power plants, continuing work on the completion of nuclear facilities in Eastern Europe (Romania, Russian Federation and Ukraine), the rise in the resale value of existing nuclear power plants in the United States and ongoing work on the construction of about 27 reactors worldwide, mainly in developing countries but also in Japan. On the other hand, other countries such as Sweden and Germany continue to opt against the construction of new nuclear power plants and for the phase out of current plants (UNECE 2006). The future prospects for nuclear remains uncertain. Based on the experience of some EU countries, as well as Japan and Korea, nuclear power plants can contribute to energy security through reducing dependence on fossil fuels. However, concerns about waste disposal, nuclear proliferation and public perceptions over safety, have undermined public support for nuclear power (World Bank 2005).
Implications

Although diversity in energy supply, by type and by origin, is considered to improve security it can be argued that diversity does not necessarily lead to enhanced security if less reliable sources of energy are introduced. For instance, the establishment of gas or oil storage facilities could create more security than diversification into intermittent wind power (van der Linde et al. 2004). However, a sustainable energy security strategy would consider wind energy as being more competitive than a conventional strategy with obvious implications for the uptake of wind energy. For instance, if the driving force behind energy security were protection against short-term oil supply disruption or, price volatility than investment into increased oil storage capacity would be an effective option. If on the other hand, a sustainability strategy is taken which accounts for the potential benefits from reducing oil dependency or meeting reduced CO₂ emissions targets than wind power would be a competitive option. The central point is that the sustainable energy security strategy would seek to find an optimal balance between multiple objectives including adherence to climate change policy, reducing oil dependency and increasing supply diversity as opposed to the narrow focus of a conventional strategy to mitigate a short-term supply disruption. A sustainable energy security path therefore takes an integrated long-term approach to energy security whereas; the conventional path focuses on short-term supply mitigation.

With respect to nuclear energy, the unresolved issues over safety and waste management strongly imply taking it off the table as a viable part of a sustainable energy path. Indeed, the WBGU (2004) calls for a complete phase out of nuclear power worldwide by 2050 as part of a transformation to a sustainable energy system. In accordance with the upperbound limits of the conceptual framework for sustainable energy security, no action should be taken that would compromise the ability of the international community to immediately place a moratorium on nuclear energy, for example, any one country having veto power over such a decision. Nuclear power also raises the issue of equity. A central aspect of a sustainable energy security system is the principle of equal access for all. Therefore, any case made against nuclear power should focus on the unresolved issues surrounding operational safety and final disposal, which poses a common threat, rather than the argument of nuclear weapons proliferation. This argument implies that some nations have the right to possess nuclear weapons while others do not. This leads down a slippery slope of assuming that some governments are better able to determine the fate of the world over others. If the principle of energy equity is to be met, it is more prudent to eliminate the option of nuclear power altogether, rather than face the risk of geopolitical conflict, which directly undermines a sustainable energy security system.

4.3.2 The Case for Renewables

Theoretical & Technical Potential

Renewables could significantly contribute to energy security if it can be utilized as efficiently, sustainably and cost-effectively as possible. On average, solar energy that reaches the earth is about one kilowatt per square metre worldwide. Power is generated from renewable energy sources at a rate of 2850 times more energy than is needed in the world today. In one day, the sunlight that reaches the earth produces enough energy to satisfy the world’s current power requirements for eight years. Even though only a percentage of that potential is technically accessible, it is still enough to provide just

---

89 No new nuclear power plants should be given planning permission. The use of nuclear power should be terminated worldwide by 2050. To this end, the WBGU (2004) recommends 1) seeking to launch international negotiations on the phase-out of nuclear power beginning with an amendment to the statutes of the International Atomic Energy Agency (IAEA); and, 2) establishing stricter IAEA safety standards for all sites at which nuclear material is stored, as well as expanded monitoring and action-taking competencies of the IAEA in the field of safeguards relating to terrorism and proliferation (WBGU 2004).

90 1) Theoretical potential identifies the physical upper limit of the energy available from a certain source. For solar energy, this would be the total solar radiation falling on a particular surface; 2) Conversion potential is derived from the annual efficiency of the respective conversion technology. It is therefore not a strictly defined value, since the
under six times more power than the world currently requires (EREC 2007). The total theoretical potential of renewable energy is 3078 times greater than the world’s total needs (Figure 4-7).

![Figure 4-6. Total Theoretical Potential of Renewable Energy](image)

EREC 2007

The amount of power that can be accessed with current technologies could provide 5.9 times the global demand for power (Table 4-7).

<table>
<thead>
<tr>
<th>Renewable Source</th>
<th>Technical Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>3.8 times</td>
</tr>
<tr>
<td>Geothermal heat</td>
<td>1 time</td>
</tr>
<tr>
<td>Wind</td>
<td>0.5 times</td>
</tr>
<tr>
<td>Biomass</td>
<td>0.4 times</td>
</tr>
<tr>
<td>Hydrodynamic power</td>
<td>0.15 times</td>
</tr>
<tr>
<td>Ocean power</td>
<td>0.05 times</td>
</tr>
</tbody>
</table>

Source: EREC 2007

efficiency of a particular technology depends on technological progress; 3) Technical potential accounts for restrictions regarding the area that is realistically available for energy generation including technological, structural, ecological restrictions, and legislative requirements; 4) Economic potential is the proportion of the technical potential that can be utilised economically; 5) Sustainable potential limits the potential of an energy source based on evaluation of ecological and socio-economic factors (EREC 2007).
Figure 4-8 shows a regional per capita breakdown of potential useable renewable energy – primarily geothermal and solar – to supply around 250 GJ each to 10 billion people, adequate for needs if intermittent sources can be stored. Europe and Asia, with around 100 GJ per capita may require imports. Nevertheless, renewable energy resources are adequate to meet all potential energy needs, despite competing with food and leisure for land use. Despite the enormous potential, widespread use of solar and wind will require new forms of energy storage and has made few inroads into primary energy supply. Although the costs of wind and photovoltaic sources have fallen dramatically over the past two decades, this was also true for conventional energy (Shell 2001). Recent oil price spikes however have brought renewed attention to the potential viability of renewables from an energy security perspective.

![Figure 4-7. Renewables Could Meet Global Energy Per Capita Demand by Region](image)


**Key Advantages**

Renewables have key advantages from a number of perspectives. From a climate change perspective, renewables have minimal net emissions of carbon in their cycle. Although unsustainable biomass burning increases global warming, emissions can be reduced by efficient technologies. From a pollution prevention perspective, renewables emit far less sulphur, lead and other toxic substances as compared to fossil fuel combustion. From a development and equity perspective, renewables can create more jobs than conventional energy developments. For instance, electricity production from fossil fuels create approximately 250 jobs-year per Terawatt-hour, wind can potentially create 10 times more and wood 4 times more (Goldemberg 2004). Reducing poverty and unemployment are high priorities in the developing world. Developing nations have underdeveloped energy infrastructures, offering an opportunity to create new jobs in modern renewable energies technologies rather than investing in outdated technologies from the developed world (Holm 2006). Some case examples that could be modelled from industrialized nations for job creation include, 40000 new renewable energy jobs created in Germany between 1990-2002 compared to 38000 jobs in the nuclear industry. Germany further expects to create an additional 250000 jobs in renewable energy by 2050. In the U.S., the potential employment of 300000 jobs in Photo Voltaic (PV) is comparable to the number of jobs in major computer industries such as Dell Computer of Sun Micro-systems. Moreover, with each direct new job that is created, there is an economic multiplier that reflects the induced spin-off by indirect
jobs created. The US Department of Energy indicates that a 10 MWp PV fabrication plant near San Francisco would produce a multiplier effect of 500%. These multipliers bring regional development benefits as well as tax incomes to state coffers (Holm 2006).

Experience Curves & Subsidies

Although representing a small contribution to the present world’s energy system, the use of new renewables is growing more rapidly at 3.5% per year compared to the growth rate of total primary energy supply (TPES) of 2% per year between 1990–2001. Table 4-8 indicates that new renewables will contribute between 6.7 – 12.9% of total energy consumption by 2020 if the growth rate observed in the period 1997–2001 continues. Growth numbers are approximate and the assumed average conversion efficiency for biomass heat is 85%; biomass electricity, 22%; biomass combined heat and power (CHP), 80%; geothermal electricity, 10%; all others 100% (Goldemberg 2006).

Table 4-8. New Renewables Contribution and Growth by Source in 2001

<table>
<thead>
<tr>
<th>Source</th>
<th>Low Contribution (EJ)</th>
<th>Low Growth rate per year (1997-2001) (%)</th>
<th>Assumed growth rate per year (%)</th>
<th>High Contribution (EJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modern biomass energy</td>
<td>6.000</td>
<td>2.5</td>
<td>10.0</td>
<td>36.695</td>
</tr>
<tr>
<td>Geothermal energy</td>
<td>2.100</td>
<td>3.0</td>
<td>10.0</td>
<td>12.843</td>
</tr>
<tr>
<td>Small hydropower</td>
<td>0.360</td>
<td>3.0</td>
<td>3.0</td>
<td>0.631</td>
</tr>
<tr>
<td>Low-temperature solar heat</td>
<td>0.200</td>
<td>10.0</td>
<td>10.0</td>
<td>1.223</td>
</tr>
<tr>
<td>Wind electricity</td>
<td>0.160</td>
<td>30.0</td>
<td>30.0</td>
<td>23.391</td>
</tr>
<tr>
<td>Solar photovoltaic electricity</td>
<td>0.004</td>
<td>30.0</td>
<td>30.0</td>
<td>0.585</td>
</tr>
<tr>
<td>Solar thermal electricity</td>
<td>0.003</td>
<td>2.0</td>
<td>2.0</td>
<td>0.004</td>
</tr>
<tr>
<td>Marine energy</td>
<td>0.002</td>
<td>0.0</td>
<td>0.0</td>
<td>0.002</td>
</tr>
<tr>
<td>Total of new renewables</td>
<td>8.900</td>
<td>39.111</td>
<td>75.375</td>
<td></td>
</tr>
<tr>
<td>World energy consumption</td>
<td>402.00</td>
<td>2.0</td>
<td>585.64</td>
<td></td>
</tr>
<tr>
<td>Fraction of new renewables</td>
<td>2.2%</td>
<td>6.7%</td>
<td>12.9%</td>
<td></td>
</tr>
</tbody>
</table>

Source: W.E.A 2004; Goldemberg 2006

At 6.7 – 12.9%, the total contribution to total primary energy supply by renewables is modest, but nevertheless represents an important contribution to global energy supply. Significant barriers will continue to prevent accelerated development of renewable energy technologies, including: 1) high capital costs, 2) economic risks, 3) regulatory obstacles, 4) limited availability of products, 5) lack of public acceptance, 6) information and technology gaps, 7) lack of infrastructure, and 8) lack of incentives. Despite declining costs in recent years, the financial challenge of overcoming high initial costs remains the greatest challenge. However, renewable energy plants are often small in size with small unit costs. This can be an advantage because large capital investments are not required. Although transaction costs can be more significant there is an opportunity to bundle many small projects into larger initiatives. Also, since renewables can be small in scale and modular, they are good candidates for
continued cost cutting. For example, experience curves\textsuperscript{91} show that cost reductions in manufactured goods can be rapid at first but then taper off as the industry matures. Experience curves resulted in industry-wide cost declines of 10 – 20\% for each cumulative doubling of production for wind generators, solar photovoltaic, gas turbines, and ethanol production (i.e. due to technology improvements, learning effects, and economies of scale) (Figure 4-9). Similar declines are expected for several other small-scale renewable energy technologies (WEA 2004; Goldemberg 2006).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure4-8.png}
\caption{Experience Curves for Photovoltaic, Windmills and Ethanol Production}
\end{figure}

Source: WEA 2004; Goldemberg 2006

Most barriers can be overcome with appropriate institutional arrangements. Although it is often argued that new renewables would require government subsides in their initial phase of development and marketing – given the potential benefits – this needs to be contrasted with the 167 billion USD government subsidies\textsuperscript{92} for fossil fuels and nuclear between 1995-1998 (Table 4-9) (WEA 2004; Goldemberg 2006).

\textsuperscript{91} The learning curve describes how marginal labour cost declines with cumulative production for a given manufactured good. The experience curve generalizes the labour productivity learning curve to include all the costs necessary to research, develop, produce and market a given product. Boston Consulting Group has shown that costs can be reduced on value added at around 20-30\% every time total product experience doubles for the industry as a whole, as well as for individual producers (Margolis 2003). The general form of the experience curve is the power curve expressed as:

\[ P(t) = P(0) \times \left( \frac{q(t)}{q(0)} \right)^{b} \]

Where:
- \( P(t) \) is the average price of a product at time \( t \)
- \( q(t) \) is the cumulative production at time \( t \)
- \( b \) the learning coefficient

\[ PR = 2^{b} \]

Where:
- \( PR \) = progress ratio. For each doubling of cumulative production the MC decreases by (1-PR) percent

\textsuperscript{92} Subsidies are all measures that keep prices for consumers below market level, keep prices for producers above market level or, reduce costs for consumers and producers by giving direct or indirect support, in a wide variety of public interventions that are not directly visible but hidden within public and economic structures (Goldemberg 2006).
Subsidies vastly distort the total external costs upon human health and environment incurred by fossil fuel production and use. Most importantly, subsidies have the effect of encouraging over reliance upon fossil fuels, which reduces energy security from a sustainability perspective and impairs the competitive market potential of renewables, which could increase energy security. The redirection of energy subsidies from fossils towards renewables would therefore be a crucial step towards a viable sustainable energy security strategy.

Table 4-9. Cost of Energy Subsidies by Source 1995-1998 (USD billion/year)

<table>
<thead>
<tr>
<th>Source</th>
<th>OECD</th>
<th>Non-OECD</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>30</td>
<td>23</td>
<td>53</td>
</tr>
<tr>
<td>Oil</td>
<td>19</td>
<td>33</td>
<td>52</td>
</tr>
<tr>
<td>Gas</td>
<td>8</td>
<td>38</td>
<td>46</td>
</tr>
<tr>
<td>All Fossils Fuels</td>
<td>57</td>
<td>94</td>
<td>151</td>
</tr>
<tr>
<td>Electricity</td>
<td>a</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>Nuclear</td>
<td>16</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Renewable and end use</td>
<td>9</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Non-payments and bailout</td>
<td>b</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>82</td>
<td>162</td>
<td>144</td>
</tr>
<tr>
<td>Per capita (USD)</td>
<td>88</td>
<td>35</td>
<td>44</td>
</tr>
</tbody>
</table>

Notes:
- a. Subsidies for electricity in OECD countries are included in fossil fuel subsidies by energy source.
- b. Subsidies from non-payments and bail out operations are not included in data by energy source.

Source: WEA 2004; Goldemberg 2006

After the first oil crisis in 1973, “new” renewable energy technologies such as electric power generation technologies from biomass, wind and solar photovoltaic (PV) emerged to decrease reliance on oil. And although renewables are expected to increase their market share of total energy consumption over the coming years they are not expected to significantly displace fossil fuels over the foreseeable future. This is largely influenced by subsidies that distort the full costs of fossil fuel use making them appear more competitive than they actually are. Between 1990 and 2004, renewables’ contribution in meeting total primary energy requirements of the EU-15 countries rose from 4.8% to 6.0%, from 12.8% to 14.8% for electricity generation, including hydro, and from 0.6% to 3.5% for electricity generation, excluding hydro. However, the rate of growth in North America declined from 6.4% to 5.6% for total primary energy, 18.5% to 15.1% for electricity generation, including hydro, and from 2.9% to 2.1% for electricity generation, excluding hydro (Yamaguchi 2005; UNECE 2006). However, with recent oil price hikes the contribution of renewables from an energy security perspective is re-emerging. Recent work extending modern portfolio theory to renewables shows that the reduction in risk through the introduction of a modest amount of renewables often outweighs the direct costs of even non-least-cost renewable sources. Moreover, the current level of renewables in many countries is less than the optimal proportion in the supply mix. This implies that countries need to not only evaluate the security of individual supply chains, but also the associated costs of risk in their energy supply portfolio against the volatility of energy markets (Feinstein 2002).
Mean Variance Portfolio Theory

Mean Variance Portfolio theory is an approach that deals with uncertainty stemming from finance theory. The general idea is that a portfolio of assets provides the best means of hedging future risks, assuming that risk reduction is attained by diversification of assets. Applying it to the electricity sector, a portfolio is a mix of power generation plants, e.g., a mix of gas-fired and coal technologies where the fuel price risk is a central concern. Based on mean-variance portfolio theory developed by Markowitz\(^\text{93}\) (1952), the expected portfolio return is related to the total portfolio risk. Both expected portfolio return and portfolio risk are weighted averages of the individual expected returns and risks. However, portfolio risk is tempered by a correlation coefficient between the individual returns (ECN 2005). This approach has been extended to renewable technologies to increase their proportional use in a supply mix.

Renewable technologies offer an effective means for climate change mitigation but there is widespread belief that increasing their deployment will raise the overall cost of generating electricity. For the last half century, least-cost power generation planning worked well due to relative cost certainty, stable energy prices, low rates of technological progress and technologically homogeneous generating alternatives. The situation today is different with electricity planning facing a diverse range of technological and institutional options for generating electricity and a future that is complex and uncertain. Attempting to identify the least-cost alternative poses a significant challenge. Mean-variance portfolio (MVP) theory is a planning method that can be economical while accounting for various uncertainties (Awerbuch 1993, 1996, 2006).

MVP evaluates conventional and renewable alternatives not on stand-alone costs, but on portfolio costs, which is the contribution to an overall portfolio generating cost relative to their contribution to overall portfolio risk. At any given time, alternatives in a portfolio may have higher costs while others have lower costs, yet the combination of resources over time can minimize the expected generating cost relative to expected risk. Although counter-intuitive, adding more costly renewables does not necessarily increase portfolio-generating costs. This is consistent with basic finance theory and derives from the statistical independence of the cost of renewables from fossil fuel price movements. This statistical independence is called the portfolio effect, which implies that all efficient portfolios contain some proportion of a fixed-cost ingredient. A portfolio effect arises when two assets within a portfolio not strongly correlated (lower correlation coefficient). As a result of combining the two assets, a significant risk reduction is obtained relative to a decrease in returns (ECN 2005; Awerbuch 2006). Portfolio theory was initially conceived in the context of financial portfolios, where it relates \(E (r)\), the expected portfolio performance or return, to \(\sigma\), the total portfolio risk, defined as the standard deviation of periodic returns. Based on a simple, two-asset portfolio the expected portfolio return, \(E (r)\), is the weighted average of the individual expected returns \(E (r)\) of the two securities:

\[
E (r) = X_1 \cdot E (r_1) + X_2 \cdot E (r_2),
\]

(1)

Where \(X_1, X_2\) are proportional shares of assets 1 and 2 in the portfolio and \(E (r_1), E (r_2)\) are expected returns for those assets.

Portfolio risk, \(\sigma\), is also a weighted average of the two securities, but is tempered by the correlation coefficient between the two returns:

\[
\sigma = \sqrt{X_1^2 \cdot \sigma_1^2 + X_2^2 \cdot \sigma_2^2 + 2 \cdot X_1 \cdot X_2 \cdot \rho_{12} \cdot \sigma_1 \cdot \sigma_2}
\]

(2)

Where \(\rho_{12}\) is the correlation between the two return streams, and \(\sigma_1\) and \(\sigma_2\) are the standard deviations.

\(^{93}\) Mean Variance Portfolio theory is an established part of modern finance theory, based on the work of Nobel Laureate Harry Markowitz 50 years ago (Awerbuch 2006).
of holding periodic returns to asset 1 and 2 respectively. The correlation coefficient, $\rho_{ij}$, represents a measure of diversity. Lower correlation among portfolio components creates greater diversity, which serves to reduce portfolio risk. More generally, portfolio risk falls with increasing diversity measured by an absence of correlation (covariance) between portfolio components. The portfolio Equations (1) and (2) indicate that adding a fixed-cost ingredient to the mix lowers expected portfolio risk, which in turn allows the portfolio to be remixed to reduce cost, even if the fixed-cost options cost more than the remaining portfolio components. Though counterintuitive, this result is based on the statistical idea that the fixed-cost ingredient, because its costs remain unchanged has $\sigma_i = 0$ and, also will be uncorrelated with the remaining ingredients. A fixed-cost ingredient with $\sigma_i = 0$ or nearly so, lowers $\sigma_p$, since two of the three terms in Equation (2) are reduced to zero. Even where $\sigma_i > 0$, the correlation, $\rho_{12}$, affects the degree of diversification and hence the mix’s overall risk (Awerbuch 2005, 2006).

As a result, efficient generating portfolios can potentially reduce generating costs while enhancing energy security by increasing the share of renewables. For example, the projected Mexico Year-2010 generating mix consists of 75% fossil generation with an overall cost of 4.8 US-cents/kWh (Table 4-10). Comparatively, efficient Mexico portfolios reduce cost by almost one-third to 3.6 cents/kWh while increasing the share of wind capacity from 3% to 9% (despite wind’s higher 5.1-US-cent stand-alone cost) (Awerbuch 2006).

Table 4-10. 2010 Business as Usual and Optimized Portfolios for Mexico

<table>
<thead>
<tr>
<th></th>
<th>Projected 2010 Portfolio</th>
<th>Efficient 2010 Portfolio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil share of portfolio mix</td>
<td>75%</td>
<td>60%</td>
</tr>
<tr>
<td>Portfolio cost (US-cents/kWh)</td>
<td>4.8</td>
<td>3.6</td>
</tr>
<tr>
<td>Renewables share of portfolio mix</td>
<td>Wind: 3%</td>
<td>Wind: 9%</td>
</tr>
<tr>
<td></td>
<td>Geothermal: 3%</td>
<td>Geothermal: 13%</td>
</tr>
<tr>
<td></td>
<td>Hydro: 20%</td>
<td>Hydro: 17%</td>
</tr>
</tbody>
</table>

Note: Assumed technology generating costs (US-Cents/kWh): Coal: 4.3; Gas: 3.2; Wind: 5.1.

Source: Awerbuch et al. 2004; Awerbuch 2006

Passive, capital-intensive renewable technologies such as wind, PV, geothermal, small hydro and possibly biomass have cost structures that are nearly fixed over time. Viewed over a dispersed geographic area, the operating costs of a generating mix containing 50% wind will fluctuate less than one without wind. Estimating the generating cost of a particular mix presents the same problems as estimating the expected return for a financial portfolio. It involves estimating cost from the perspective of market risk. Current approaches for evaluating and planning national energy mixes are biased towards high risk fossil alternatives, while marginalizing the value of PV, geothermal, wind and other low-risk, fixed-cost, passive, capital-intensive technologies (Awerbuch 2006).

Fixed-cost renewables can cost-effectively hedge the risk of oil price volatility. Oil price volatility can depress macroeconomic activity measured by GDP growth, employment and inflation. Energy mixes that are exposed to fossil risk reduce energy security (Awerbuch & Sauter 2005). Energy security generally focuses on the threat of abrupt supply disruptions but another aspect is the impact upon energy security due to price volatility (Awerbuch & Sauter 2005; Awerbuch & Berger 2003; Toman 2002; Leiby 2002). Generating portfolios that increase the share of renewables can minimize the level of risk and costs needed to enhance energy security while meeting environmental objectives (Awerbuch 2006).
Figure 4-9 shows the risk-return for various EU portfolio mixes. Portfolio risk is measured as the standard deviation of historic annual outlays for fuel, operation and maintenance (O&M) and construction period costs. Portfolio return is expressed as kWh/US-Cent – the inverse of generating costs. Higher returns represent lower costs. Figure 4-10 shows that an infinite number of portfolio mixes with a different mix of technologies occur at different risk-return locations. The dark upward indicates the efficient frontier (EF), which depicts the location of all optimal portfolios. Along the EF, return cannot be increased without accepting more risk. Figure 4-10 indicates that different portfolio mixes can produce very similar risk-return characteristics shown by the risk-return of the EU-2010 is nearly identical to a portfolio consisting of 100% coal. In any risk-return vicinity there are a number of significantly different feasible portfolio combinations. This enables the optimization to locate mixes with desired risk-return properties, but with a higher share of renewables improving the portfolios. The EU-2000 mix has a generating cost of approximately 0.033/kWh. Wind costs about 10% more, yet increasing its share of the mix does not raise overall cost. The EU-2000 mix has a 1% wind share, while Portfolio N, which contains 53% wind lowers risk without raising cost. Although, 53% wind shares may not be feasible given the limitations of existing power networks, the key point is that it is possible to construct portfolios with moderately higher wind shares of 10–20% without increasing generating cost.

![Figure 4-9. EU 2000 and 2010 Generating Portfolios Cost & Risk](Image)

Source: Awerbuch & Berger 2003 in Awerbuch 2006

Although the EF can depict a range of optimal possibilities various constraints are not depicted. For example, energy policies specific to nuclear or climate change will shorten the EF thereby reducing the range of possible choices. Generally, there can be a number of political constraints not explicitly stated in portfolio analysis. For example, policy makers would likely only consider solutions that cost less than the projected EU target mixes (e.g. that lie above the EU-2010 mix). Similarly, policy makers may not be interested in high-risk low-cost solutions such as 100% gas although these are included for comparative purposes. It is reasonable to assume that policy makers will focus primarily on the region surrounding the projected 2010 target mix (Awerbuch 2006). In other words, the EF assumes no policy constraints and depicts a theoretical potential range of options.

Another potential constraint of Portfolio theory is that it assumes that risk reduction is achieved by a diversification of assets, which may often be true. However, the argument could be put foreword from...
a conventional energy security perspective that increasing the share of intermittent renewable technologies may in fact reduce energy security. On the other hand, this should be weighed against the potential benefits derived from a reduction in emissions and enhanced protection from oil price volatility. Although the portfolio method can be used to support an environmentally optimal generating mix, it is constrained to large generators. Small generators do not operate at a scale for relevant portfolio analysis. By definition, portfolio theory assumes a broad approach, i.e. large companies, national portfolios or large service territories (ECN 2005). Consequently, this approach may have less relevance for small scale off-grid renewable development in developing nations, where access to modern energy could play an important role for poverty alleviation in rural areas, but is often financially constrained. In principle however, if portfolio theory could support an accelerated uptake of renewables on a larger scale, the theoretical savings gained from reduced risk to fossil price volatility could be reallocated towards small-scale rural energy programs.

Making Renewables Competitive

Although high oil prices and increasing environmental awareness are raising interest in renewable energy a rapid transition away from fossil fuels has not occurred. The relatively high costs of most renewables lack of government-provided economic incentives, and easy access to oil, gas, and coal hinders the growth of renewables. Over the next 20 to 30 years, renewables will become more cost competitive as environmental concerns rise. In addition to declining costs for renewable technologies, governments can improve the prospects for renewable energy through tax credits and other economic incentives. Hawaii, for example, has the largest penetration of installed solar hot water heating units per capita within the United States largely due to a 35% tax credit to residents who purchase passive or active systems. After several years, solar water heating units more than pay back for themselves. In light of the current security risk premium of several US dollars on a barrel of oil, a renewable energy tax credit can be viewed as a risk reducer, because of the resulting drop in reliance on imported and polluting fossil fuels (Dorian et al. 2006). Other strategies to increase the expansion of renewables include:

➤ Agreed upon national renewable energy quotas. In order to minimize costs within a scheme, a worldwide system of internationally tradable renewable energy credits could be set. The system could commit each country to meet a part of its quota through domestic generation.

➤ Continuing market penetration strategies (e.g. subsidy schemes over limited periods, guaranteed feed-in tariffs). Until significant market volume has been reached, guaranteed feed-in tariffs where payments decline over time could be highly effective. When a sufficient market volume of individual energy sources has been reached, assistance could be transformed into a system of tradable renewable energy credits or green energy certificates.

➤ Upgrading energy systems to permit large-scale deployment of fluctuating renewable sources. This includes grid control, implementing appropriate control strategies for distributed generators, upgrading grids to permit penetration by distributed generators as well as expanding grids to form a global link. This could be followed by establishing infrastructure for hydrogen storage and distribution, using natural gas as a bridging technology.

➤ Strengthening human-resource and institutional capacities in developing countries and intensifying

94 A feed-in tariff is a renewable energy law, which obliges energy suppliers to buy electricity produced from renewable resources at a fixed price, usually over a fixed period. These legal guarantees ensure investment security, and support viable renewable energy technologies. Proponents argue that the feed-in model could catalyze an energy revolution through CO₂ reduction, market development, job creation and improved energy security. It was recommended in the Stern Report as the best policy tool for the fastest, lowest-cost deployment of renewables (Mendonca 2007).
technology transfer to improve framework conditions for sustainable energy systems (BGWU 2004; WEA 2004; Mendonca 2007).

4.3.3 Infrastructure Security

Centralized energy infrastructure achieves economies of scale in construction and operation, and when designed and maintained adequately has a strong record of technical reliability and environmental compliance. However, large centralized facilities can be vulnerable to large-scale catastrophe and loss. Technological change is redefining the scale at which efficiency and economy can be captured for instance, in combined-cycle gas turbines, and over the longer term through efficient micro turbines, fuel cells, and sunlight-to-electricity converters. These distributed energy systems can complement large centralized facilities enhancing physical security due to their modularity and geographic diversity (Feinstein 2002). Enhanced infrastructure security through decentralization can also support the development of small-scale renewables, a central feature in a sustainable energy security strategy particularly from the perspective of poverty alleviation in developing nations. However, large-scale systems including hydro and wind used to service distant urban centres would still be prone to transmission system risks and failure (Farrell et al. 2004).

Diversifying infrastructural design is another way to reduce vulnerability to design error, which could lead to widespread failures or pre-emptive shutdowns. For instance, although standardized designs in nuclear plants can improve economies of production it also increases exposure to the possibility of systematic failures. A range of plant designs could therefore be pursued as a safety management measure (Farrell et al. 2004). If a less than sustainable energy security path is taken and nuclear is pursued, than diversifying design could be a precautionary measure imposed upon industry despite potentially higher costs. The benefits would be enhanced security if the nuclear development was realized, but more importantly could be an incentive to shift investment away from nuclear in the first instance due to imposed higher costs.

None of the above measures to enhance energy infrastructure can be achieved without increased investment. Nor, will improved energy efficiency remove the need for substantial energy investment. As previously discussed, the IEA (2006) projects total investment requirements for the period 2003-2030 to be around 20 trillion USD. Most of this investment is required for power generation, transmission and distribution in developing nations. In order to encourage investments on this scale for the power sector governments will need to:

➤ Promote policies to secure adequate cash flows in the public sector and help finance new investment and maintenance and not allow state utilities to be inefficient or not fully recover cost.

➤ Encourage private investment through streamlining procedures, improving clarity and enforceability of contracts, and creating conditions that attract and facilitate competitive private investment within a framework of competition.

For the oil sector investment strategies include:

➤ Increasing the effectiveness of National Oil Companies (NOCs), or state dominated joint ventures, which account for a major part of the world’s oil and gas supply and its future growth, by creating governance frameworks that optimize operational efficiency and investments (including trade-offs between state investment in exploration and production, and non-oil sector public expenditures). Under existing institutional frameworks, a significant portion of necessary global investment in oil and gas production capacity will come from a handful of Middle Eastern NOCs. Consequently, their governance frameworks will be of crucial importance.
➤ Reducing barriers to private investment. In some countries with limited sector experience and access to capital, private investment can be important. Finding ways to effectively use the ability of private investors can help mobilize needed investment and facilitate the spread of new technologies and processes.

➤ Improving transparency in the oil sector from consumption, stock, production and resource base along with revenue flows creates a better investment environment (World Bank 2005).

Export-dependent energy producers face the challenge that instability in energy prices complicates macroeconomic management and can undermine long-term growth. They also face the challenge of diversification to reduce dependency on oil and gas exports. Many countries have highlighted the importance of security of supply, market transparency and the need to cooperate and encourage greater energy investment. Significant investments in cross-border trade in energy, including pipelines and electricity interconnections have reduced some of these concerns. Regional integration can enhance energy security demonstrated by recent projects in Africa, including the Southern Africa Power Pool project, the West Africa Power Pool project and the West Africa Gas Pipeline project, as well as the gas pipeline from Mozambique to South Africa. Rising oil prices has increased urgency for improving information and transparency for example through the Joint Oil Data Initiative (UN 2006).

Infrastructure investment needs are a crosscutting theme and could be an important catalyst for a sustainable energy security strategy. On the one hand, infrastructure decentralization could imply increased investment into new renewable or clean technologies to diversify supply and enhance infrastructure security; while, cross border joint infrastructure investment could play an important role in improving foreign relations by increasing energy interdependency minimizing the potential for regional conflict.

### 4.3.4 Strategic Reserves

Strategic oil reserves have been the backbone of the international energy co-operation among OECD member states facilitated through the International Energy Agency. The effectiveness of strategic stocks in responding to a supply disruption is determined by their volume and the ability to transport and process the oil where the shortfall arises. Sufficient strategic oil reserves can deter a producing country from tightening supply because a release from the stocks and the resulting price impact can be negative for the exporter. A release from the strategic oil reserve can also contain a crisis, because the availability of oil is kept at a higher level than without the release. In a situation of acute disruption, strategic reserves allow the country to consume oil without receiving new supplies (van der Linde et al. 2004). As a strategic tool, the storage of gas is considerably more expensive and logistically far less effective than oil stocks. The costs of gas storage are determined by the availability of adequate geological facilities such as gas fields and salt caverns which are unevenly spread among OECD member states. If member states were to store gas in other member states, the lack of infrastructure poses severe logistical and cost limitations. Given these constraints gas is not a cost effective tool for certain countries in the event of a supply crisis (van der Linde et al. 2004).

A vulnerability of strategic oil reserves is that a supply disruption may coincide with the removal of transportation or processing capacity from the market particularly when these facilities are owned and controlled by the producer, which eliminates the use of strategic reserves. For instance, in 1990, removal from the market of Kuwait’s refining capacity created a tight supply situation and in 2000, U.S. refining capacity was insufficient to meet US product demand. Oil released from the strategic petroleum reserve could not be processed and was therefore ineffective. Generally strategic petroleum reserves are more effective against random, short-term supply disruptions rather than sustained price increases. Strategic oil reserves may therefore be a precaution against possible attacks on the petroleum infrastructure notwithstanding that the reserves do not become a likely target (van der Linde et al. 2004; Farrell et al. 2004).
The important implication from a sustainable energy security perspective is that the current security system based on OECD strategic reserves does not include emerging economies such as China and India despite the fact that demand centres are shifting towards these two countries (Yergin 2006, 2007). To achieve a sustainable energy security system, it will be crucial to ensure that emerging economies are brought to the table to enhance global energy security rather than pursue conventional security policies that may lead to a collision of national interests and geopolitical tension. An important opportunity now exists to broaden the scope of the energy security system to account for the structural shifts in demand and supply that are reshaping the energy security paradigm, which can either move towards sustainability or geopolitical fragmentation.

4.3.5 Energy Efficiency

Improvements in end-use efficiency can play a crucial role in a sustainable energy security strategy for a number of reasons. For instance, increasing end-use efficiency can achieve an equal level of energy services with lower energy input requirements reducing fossil fuel dependency and extending the life of existing reserves (Goldemberg 2006). One of the foremost challenges facing global energy security is to ensure adequate access to modern energy in developing nations. Energy efficiency can address this challenge from the perspective of macroeconomic development and the provision of basic energy.

Decoupling Energy $\Leftrightarrow$ GDP

From a macroeconomic perspective, the aggregate impact of energy efficiency improvements on the economy can be considered through an energy-GDP (Gross Domestic Product) correlation, which can be expressed as follows. An economy consists of a number of energy-utilizing activities each of which has an energy intensity, $I_j$, and a contribution, $C_j = f_j \times GDP$, to the GDP, where $f_j$ is the fraction of GDP from activity $j$. Hence, the energy demand $E$ is the sum of the energy demands, $E_j = C_j \times I_j$, of the various activities:

$$E = \sum E_j$$

$$= \sum [C_j \times I_j]$$

$$= \sum [f_j \times GDP \times I_j]$$

$$= \sum [f_j \times I_j] \times GDP$$

Therefore, energy demand is proportional to GDP if $\sum [f_j \times I_j]$ is a constant. The energy-GDP correlation where a country’s energy consumption is proportional to GDP is valid only during periods when there is no change in the economy’s (1) energy efficiency and (2) structure. If there are changes in energy intensity due to efficiency improvements, process changes, product changes or changes in contributions of different activities to GDP (e.g. share of basic materials manufacturing declines and the share of less energy-intensive activities increases), the proportionality weakens. A decrease of $\sum [f_j \times I_j]$ can offset an increase in GDP so that coupling between GDP and energy is reduced. There can even be a decoupling so that there is a decrease in energy consumption associated with an increase in GDP. The historical evidence for this reduction of coupling between energy and GDP has been seen in various industrialized countries. For example, energy intensity in the UK has declined approximately 1% per year since 1880$^{95}$ (Reddy and Goldemberg 1990; Williams et al. 1994).

$^{95}$There are three factors responsible for the behaviour of energy intensities: 1) the improvement over time of the efficiency of production of energy carriers (e.g., the kWh generated per tonne of coal burned has improved); 2) the improvement of energy end-use technologies - the energy to perform an energy service (e.g., kWh to achieve a certain illumination) or produce a product (e.g., kWh per tonne of aluminium) has decreased over the years; 3) structural changes in the use of materials whereby economies become less materials-intensive at higher levels of
Most significantly, not only can the link between rising energy consumption and GDP growth be broken by using energy more efficiently, but also investing in energy efficiency can be less costly than investing in supply. This could be achieved through commercially available end-use technologies able to provide energy services with far less energy input than technologies commonly used in developing nations (Goldemberg 1997; WEA 2004). Efficiency gains can be made along the entire energy supply chain including: i) extraction of primary energy and conversion into energy carriers, ii) transmission and distribution of energy carriers, iii) end-use in existing installations through improved operation, maintenance, retrofits and, iv) end-use in new installations, equipment, etc. (Goldemberg et al. 1994).

The technical and economic potential for reducing energy demand through efficiency is significant. For example, energy use can be reduced by 10-40% for extraction/conversion, transmission and distribution, 20-50% for existing installations and 50-90% for new installations (Goldemberg et al. 1994). Cost-effective end-use efficiency improvements could reduce approximately one-third of future electricity requirements in developing countries. This does not eliminate the need to expand supply, but as end-use efficiency increases the necessary supply to provide equal if not better energy services is reduced. This is particularly relevant for developing nations, because much of the infrastructural and equipment investment for economic growth has not yet been made (Goldemberg et al. 1994).

**Basic Energy Services**

The other key contribution to sustainable energy security that improved efficiency can make is the provision of basic energy services in developing nations. The crucial issue for many developing nations is the cost-effective provision of basic services. For example, the switch from kerosene wick-lamps to fluorescent tube lights in Southern India caused household lighting expenditures to be halved, while increasing illumination by a factor 19 (Goldemberg et al. 1994). Policies aimed at increasing energy efficiency in developing nations could therefore not only meet basic needs but also improve the standard of living despite severely low incomes.

The potential contribution of efficiency in providing basic services are best illustrated by an energy use scenario (Table 4-11) developed for a hypothetical warm climate developing country. The scenario assumes amenities equal to Western Europe in the 1970s but uses best available technologies in the 1980s. The result is that an increase of up to 1 kilowatt per capita energy consumption could in principle, allow developing nations to not only meet basic needs but also substantially raise their current standard of living without significantly increasing per capita energy consumption.

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96 The extra foreign exchange required for more efficient end-use technologies can be offset by reduced foreign exchange for new energy supplies (Goldemberg et al. 1984).

97 Cooking with modern energy carriers requires far less energy input reflected both in improved efficiency (40 to 50% versus 12 to 18% for traditional fuel wood stoves) and increased control of stoves fuelled with modern energy carriers (Goldemberg et al. 1984).

98 Approximately 20% more than the average final energy use rate among developing nations in 1986 (Goldemberg et al. 1985).
Table 4-11. Final Energy Use Scenario for a Warm Climate Developing Country With Amenities (minus space-heating) Comparable to Western Europe in the 1970s utilizing Best Available Energy Technologies

<table>
<thead>
<tr>
<th>Activity</th>
<th>Average Rate of Energy Use (Watts per Capita)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electricity</td>
</tr>
<tr>
<td>Residential</td>
<td></td>
</tr>
<tr>
<td>Cooking</td>
<td></td>
</tr>
<tr>
<td>Hot water</td>
<td></td>
</tr>
<tr>
<td>Refrigeration</td>
<td></td>
</tr>
<tr>
<td>Lights</td>
<td></td>
</tr>
<tr>
<td>TV</td>
<td></td>
</tr>
<tr>
<td>Laundry washer</td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td></td>
</tr>
<tr>
<td>Automobiles</td>
<td></td>
</tr>
<tr>
<td>Intercity buses</td>
<td></td>
</tr>
<tr>
<td>Passenger trains</td>
<td></td>
</tr>
<tr>
<td>Urban mass transit</td>
<td></td>
</tr>
<tr>
<td>Air travel</td>
<td></td>
</tr>
<tr>
<td>Truck freight</td>
<td></td>
</tr>
<tr>
<td>Rail freight</td>
<td></td>
</tr>
<tr>
<td>Water freight</td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
</tr>
<tr>
<td>Raw steel</td>
<td>28</td>
</tr>
<tr>
<td>Cement</td>
<td>6</td>
</tr>
<tr>
<td>Primary aluminium</td>
<td></td>
</tr>
<tr>
<td>Paper and paperboard</td>
<td></td>
</tr>
<tr>
<td>Nitrogenous fertilizer</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>65</td>
</tr>
<tr>
<td>Agriculture</td>
<td>4</td>
</tr>
<tr>
<td>Mining &amp; Construction</td>
<td>59</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1049</strong></td>
</tr>
</tbody>
</table>

Source: Adapted from Goldemberg et al. 1985

The results of the scenario indicate that increased amenities across all sectors could be achieved by exploiting cost-effective efficient technologies using high-quality energy carriers. Increased efficiency could therefore meet both human development and energy security goals, without straining energy supply. Moreover, investing in efficiency can potentially be more cost-effective than investing in supply. For example, in the Brazilian electricity sector an investment in energy-efficient end-use technologies corresponded to capital savings of 19 billion USD by eliminating the need for installing 21 GW (e) of additional supply capacity (Goldemberg et al. 1985). Efficiency gains could liberate scarce resources, which could be allocated towards other socio-economic objectives such as subsidizing electricity for the poorest quintile households (Goldemberg et al. 1994).
Moderating end-use energy requirements could also allow a higher proportion of needs to be secured through domestic and renewable sources while corresponding reductions in energy imports could enhance energy security. Improving energy efficiency can therefore potentially offer a ‘win-win’ option for addressing concerns about energy security (Feinstein 2002; World Bank 2005). Efficiency savings would also reduce GHG emissions and local air pollutants meeting environmental and human health goals under a sustainable energy security strategy.

4.3.6 Energy Trade & Interdependence

Energy trade is another crosscutting theme, which can play an important role in a sustainable energy security strategy. A major share of energy supply crosses international borders with trade extending well beyond raw energy products to include oil product distribution and infrastructure development such as electricity grids or LNG distribution networks (Feinstein 2002). Developers make large upfront capital commitments hoping that demand and prices remain reasonable over the life span of a project, typically 30-40 years. Oil producers recognise oil as traded commodity and seek security of demand as much as oil importers want to ensure security of supply (WEA 2004; Birol 2006). This creates an energy interdependency, which can enhance cross border cooperation since trade requires continued collaboration and commitment to maintain demand and supply (Yergin 2006).

An area for enhanced international trade is electricity system integration, which potentially has benefits for long-term security, economics of scale, access to more competitive fuel sources, as well as short-term reliability (Feinstein 2002). The integration of energy systems also highlights interdependency from a shared risk perspective. The vulnerability of integrated generating systems was shown on the U.S. coast when Hurricane Katrina caused the first integrated energy system crisis (Yergin 2006). From an inter-regional trade perspective LNG has significant potential for trade growth but can be impaired by geopolitical tensions arising from differing government approaches towards energy security and development99. Governments however, have an important role to play in facilitating cross border trade and investment. This can include establishing national legislation to encourage investment, participating in international treaties to facilitate trade and transit, or encouraging dialogue between suppliers and customers to achieve mutually acceptable approaches to common energy trade and security issues.

In terms of international trade frameworks, the World Trade Organization (WTO) was resistant to the inclusion of energy carriers into the GATT rules, although they fall within the scope of these provisions. The hesitation was due to the role of the energy sector in national security of supply, the OPEC countries’ non-membership of the WTO and the regulation of the energy sector at the national level, especially the status of state-sector energy monopolies. For the power industry, international trade in electricity was not envisaged when GATT was established. It was only with the Uruguay Round in 1994 that various energy carriers including coal, gas and oil and electricity became integrated into the world trade regime. This was due to the accession of various OPEC countries into the WTO and the liberalization of energy markets around the world (WBGU 2004). Although energy market liberalization has been progressive, the WTO views subsidies on energy provision and consumption as the most important barrier to further liberalization of energy trade. An argument put foreword by the WTO is that full integration of the sector under WTO rules and the stringent application of the WTO Agreement on Subsidies and Countervailing Measures could reduce subsidies and contribute to climate protection. According to the WTO, the dismantling of all subsidies by 2010, supported by progressive

99 Conflicting government views can constrain energy trade and reduce an opportunity to enhance regional collaboration, which would form part of a sustainable energy security strategy. For example, market forces in the Russian Federation are constrained because Russia favours large state owned or controlled enterprises in the oil and gas sector, state control of oil and gas pipeline facilities, export pipelines, and limits on foreign ownership and control of energy assets. Nearby Kazakhstan, on the other hand has been more open to the development of energy resources by the private sector (UNECE 2006).
environmental policies could prevent around 6% of CO₂ emissions worldwide (WTO 2001 in WBGU 2004). The possible drawback of this from a sustainable strategy perspective however, is if the full integration of the energy sector into the WTO would also restrict subsidies to promote renewables and other advanced energy technologies on both the demand and supply side.

Uncertainty in global energy markets has increased in recent years. Energy security is more than ever a matter of managing risk and coping with uncertainty. Deepening the dialogue between energy producers and consumers will assist all stakeholders in handling uncertainty and help industry mobilise investment creating an opportunity to strengthen cooperation. Improving market transparency through effective information exchange and cooperating on policies will also facilitate energy trade and enhance security (Birol 2006; UNECE 2006).

4.3.7 Enhancing Geopolitical Relations

In a globalizing energy market, achieving energy security implies enhanced geopolitical relations. The need for geopolitical cooperation is already implied under various international agreements and conventions on climate change, development and trade. These agreements and conventions have in place frameworks to facilitate dialogue, settle disputes and build consensus around common objectives. Opportunities should be taken to utilize these frameworks to enhance cooperation over energy security issues particularly within the context of sustainability and climate change where a rich dialogue and critical mass of consensus has already been reached. In other words, “leapfrogging” is a concept that could also apply to the policy and geopolitical realm building upon established channels of communication and international deliberations that have painstakingly proceeded over past years. Other concrete ways to increase geopolitical relations include joint-investments into regional infrastructure, pursuing long-term agreements to ensure security of demand and supply, or encouraging wider adoption of standing treaties such as the Energy Charter (WEA 2004).

Geopolitical relations and foreign policy have always played a central role in energy security policies resulting in government relationships that can take a number of forms. Some forms are more appropriate than others however from a sustainable energy security perspective. For example, although the special U.S.-Saudi bilateral relationship has increased energy security from a conventional perspective, it is not a model that reflects energy sustainability for two central reasons; First, it has effectively locked the world’s largest energy consumer into perpetual oil dependency and is founded upon military projection, which is in direct contravention to global peace and sustainability, and second, the nature of a bi-lateral relationship excludes open dialogue and wider participation with the international community. This foreign policy tactic is based upon geopolitical competition rather than cooperation, which seeks to gain a position of advantage to circumvent rival powers. From a sustainability perspective, such a model is unacceptable, particularly since energy security decisions taken by nations such as the U.S. or China will have repercussions for the rest of the world. The need for countries like the U.S. and China to engage in open dialogue with the international community is evident.

By contrast, international forums and other multi-lateral frameworks could be an effective model for enhancing energy security from a sustainability perspective. As previously discussed, energy trade can provide a basis to enhance political relations where the central goal of consumer countries is to create security of supply, while producer countries seek security of demand. Energy interdependence has brought producers and consumers together. This is reflected in longstanding efforts between Venezuela and France in the 1970s and early 1980s to bring producer and consumer countries together which initially met with failure but by the second half of the 1980s dialogue was finally achieved. Over the past decade, the consumer-producer dialogue has gained importance and has been institutionalised in the International Energy Forum (IEF) with a Secretariat in Riyadh, Saudi Arabia. Around 80 countries now participate in the bi-annual meetings of the energy ministers. The agenda of the IEF was at first predominantly focused on oil issues, but recently gas, investments and public-private partnerships have emerged on the agenda. The IEF has become an important channel for co-operation
and understanding of interests and problems between participating countries (van der Linde et al. 2004). Regional and international institutions can be a neutral forum to enhance dialogue between nations and encourage collaborative action (UN 2006). Table 4-12 provides a sample of key institutions and their functions operating at different capacities aimed at improving multilateral relations and cooperation to overcome challenges related to the global energy system.

Table 4-12. Global Energy Institutions, Key Policies and Functions

<table>
<thead>
<tr>
<th>Functions</th>
<th>Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research &amp; Consultancy</td>
<td>Intergovernmental Panel on Climate Change (IPCC)</td>
</tr>
<tr>
<td></td>
<td>International Energy Agency (IEA) – World Energy Outlook (WEO)</td>
</tr>
<tr>
<td></td>
<td>United Nations Collaborating Centre on Energy and Environment (UNCCEE)</td>
</tr>
<tr>
<td></td>
<td>World Energy Council (WEC), United Nations Development Program (UNDP),</td>
</tr>
<tr>
<td></td>
<td>United Nations Department of Economic and Social Affairs (UNDESA) – World</td>
</tr>
<tr>
<td></td>
<td>Energy Assessment (WEA)</td>
</tr>
<tr>
<td>Information &amp; Technology Transfer</td>
<td>Political Declarations (UNCED, CSD-9, WSSD, etc.)</td>
</tr>
<tr>
<td></td>
<td>International treaties (ECT, UNFCCC, GATT, etc.)</td>
</tr>
<tr>
<td></td>
<td>International Atomic Energy Agency (IAEA)</td>
</tr>
<tr>
<td></td>
<td>UNEP, UNDP, UNDESA, etc.</td>
</tr>
<tr>
<td>Coordination</td>
<td>IAEA</td>
</tr>
<tr>
<td></td>
<td>European Union (EU)</td>
</tr>
<tr>
<td></td>
<td>UNDESA</td>
</tr>
<tr>
<td></td>
<td>Ad-hoc Interagency Task Force on Energy</td>
</tr>
<tr>
<td>Implementation &amp; Management</td>
<td>UNDP</td>
</tr>
<tr>
<td></td>
<td>UNEP</td>
</tr>
<tr>
<td></td>
<td>United Nations Educational, Scientific and Cultural Organization (UNESCO)</td>
</tr>
<tr>
<td></td>
<td>World Bank</td>
</tr>
<tr>
<td></td>
<td>Food and Agriculture Organization (FAO)</td>
</tr>
<tr>
<td>Resource generation and distribution, financial services</td>
<td>Private investment (Foreign Direct Investment)</td>
</tr>
<tr>
<td></td>
<td>Global Environment Facility (GEF)</td>
</tr>
<tr>
<td></td>
<td>World Bank</td>
</tr>
<tr>
<td></td>
<td>Regional Development Banks</td>
</tr>
</tbody>
</table>

Source: Adapted from WBGU 2004

4.4 Contribution of the Sustainable Energy Security Framework

The strategies discussed under the proposed sustainable energy security framework are not new. In fact, they are the same strategies and issues that have played a central part of the energy security debate for decades. But in parallel to energy security, the international community has now brought forward a new set of global priorities most notably climate change mitigation and sustainable development clearly reflected in the Kyoto Protocol and the Millennium Development Goals. These global priorities constitute the need for a fundamental shift in the way energy security is pursued. The need to change the perspective over what energy security means in the 21st century is the underlying basis of this thesis.

The proposed framework is a preliminary attempt to take an integrated approach in considering various issues, policies and strategies under a framework that explicitly demonstrates the interconnections between sustainability and energy security. In doing so, conventional energy security
strategies both on the demand and supply-side along with geopolitical approaches have been assessed from a sustainability perspective where the fourth dimension of geopolitical cooperation has been integrated into the traditional three dimensions of sustainability (i.e. economy, environment, society). Current understanding of the role of energy for sustainable development has been brought to bear upon the field of energy security where the central argument is that energy security policies and strategies must account for the role that energy plays in broader priorities such as climate change and poverty reduction. This implies that a sustainable energy security paradigm must extend far beyond the conventional focus on security of supply.

The conventional energy security paradigm and the strategies and polices that have arisen from it has perpetuated society’s reliance on fossil fuels bringing into conflict the interrelated goals of enhancing energy security, mitigating climate change, alleviating poverty and increasing geopolitical stability. The central contribution of a new energy security paradigm based on sustainability is that it can bring renewed focus to energy diversification and efficiency, pursue policies to reduce demand for fossil fuels with an aim to eliminate oil dependency altogether, particularly in developing nations where impacts are felt the hardest, and stimulate a serious reconsideration about the viable contribution that renewables can make to security of energy supply.

Future Research

The following future research could be pursued to build upon this work.

- Full Cost-benefit analysis to compare various energy security strategies both on the demand and supply-side, taking into account all benefits accrued from pursuing a sustainable strategy versus a conventional strategy (i.e. internalizing all externalities related to various demand and supply-side energy security strategies).

- Exploring the potential of cross-border energy infrastructure joint investments as a cooperation building tool between governments and industry and assess what impact this may have for medium or long-term energy supply agreements (e.g. comparative case-analysis of existing and planned cross-border energy infrastructure developments).

- Comparative analysis of national energy security strategies from a resource base perspective (i.e. net-importers vs. net-exporters). What strategies could be mutually beneficial for securing energy demand and supply agreements.

- A relatively large information gap exists concerning the impacts of energy market volatility upon developing nations particularly at the household level. There is a need to increase the state of knowledge about vulnerabilities and local strategies that have been taken at the household level.

- National level energy security strategies for developing nations. Supply side vulnerability assessments utilising Mean Variance Portfolio (MVP) method. Generally there needs to be increased understanding about the relevance of MVP for developing nations. Comparative analysis using MVP between developing nations could determine strengths and weaknesses of the method in the developing nations context.

- There needs to be increased understanding about the role of regional energy trade in developing nations as a way to enhance energy security. This could be assessed from a number of perspectives including institutional arrangements, appropriate pricing mechanisms, policy interventions, investment needs, capacity building, technology transfer, etc.
5 CONCLUSION & REFLECTIONS

The modern energy security paradigm emerged in the wake of the oil crises of the 1970s and is rooted in a history of policies and practices that do not adequately reflect the dynamics and complexities of the present day. Conventional energy security policies have had both direct and indirect implications for continued oil dependency, military conflict, global warming and disproportionate impacts upon the poor. Moreover, despite inconclusive evidence, political events in key oil producing regions have been held responsible for negative economic effects upon industrialized nations. These assumptions have been used to justify military intervention into oil producing regions around the world, most notably the Persian Gulf, at an enormous cost upon human populations and environment. The conventional energy security paradigm has brought the global energy system into direct conflict with the principles of sustainability and is no longer adequate for addressing the interrelated challenges associated with a rapidly changing global energy system.

The global energy system is undergoing fundamental changes calling for a new understanding of global energy security. Central features of this change include shifting demand and supply centres away from the OECD towards developing nations, increasing vulnerability and threat from volatile oil markets, the fear of terrorism and vulnerable infrastructure, heightened geopolitical tension due to competition over concentrated resources, and the convergence of global agendas including climate change and sustainable development with the energy security debate. As a result, there needs to be a re-evaluation of long-held norms concerning energy risk, vulnerability and security in order to move towards an energy security system that responds to the emerging challenges of today and the future. Therefore, a new paradigm of energy security must reflect the interlinkages between the social, economic, environmental and geopolitical challenges associated with a rapidly changing global energy system while remaining consistent with the principles of sustainability. As such the central hypothesis of this thesis is maintained:

The conventional energy security paradigm is no longer adequate for addressing the increasingly complex and interconnected challenges associated with the current global energy system. A new concept of energy security is therefore required which accounts for new and converging global priorities including climate change and sustainable development.
This satellite image shows the earth at night reminding where energy is consumed in the world, who has access to it, and why.

- Martino Tran, 2007 –
Bibliography


Redefining Energy Security for the 21st Century
An Empirical Analysis of the Evolution of Energy Security Towards Sustainability


Appendix 1. Contact List

Informal discussions were held with the following key resource persons active in the energy and development field throughout March and April, 2007 in Vietnam and Thailand. The overall objective was to gain understanding about energy development challenges at various levels in the developing nations context. Although these discussions are not explicitly integrated into this thesis they played an important role in evolving the concept of energy security as an overarching analytical framework to encompass the myriad issues now confronting the global energy system underpinning the central argument of this thesis that the concept of energy security must extend far beyond the conventional focus on security of supply.

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