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Review and identification of opportunities for the diversification of the energy matrix, including renewable energies, with awareness of countries' needs to ensure a proper balance between food security and energy concerns

The future energy matrix and renewable energy: implications for energy and food security

Note by the UNCTAD secretariat

Executive summary

Global energy demand has continued to increase, with major developing countries acting as the main driving force behind such increases. However, the world energy balance is dominated by fossil fuels. One major issue raised by this is how to change the future energy matrix towards more sustainable and renewable sources of energy.

This background note reviews the state and prospects of the future energy matrix and, in particular, the potential role of renewable energy sources. It also examines the issue of biofuel production from the perspective of its implications for both energy and food security. It emphasizes the importance of adopting an integrated approach to energy security within the framework of which trade-offs are carefully evaluated against the background of national and global economic development challenges.

Introduction

1. For many years, fossil fuels – including coal, crude oil and natural gas – have been the main source of commercial energy¹ for industrial production, heating and transportation. Hydrocarbons, and especially petroleum, have also been used in the pharmaceutical, building and clothing industries, as well as for fertilizers, foodstuffs, plasticware and paints. The inclusion of other energy sources, such as nuclear and renewables – wind, solar, geothermal, water and biomass – in the energy matrix has been marginal, because of high costs and underdeveloped technologies. In the case of nuclear power, there are additional safety concerns, including the long-term disposal of radioactive waste.

2. However, recognition of the damaging environmental impact from excessive dependence on fossil fuels, along with growing concerns about the supply of some fossil fuels to meet rising global demand for energy, has brought into focus the need for a cleaner and more diversified energy mix. Hence, renewable energy, including biofuels, has received growing attention. Furthermore, energy supply shocks, beginning with the oil crisis in 1973, have alerted policymakers, in developed and developing countries alike, of the need to move away from reliance on a single source of energy. The recent shocks, which caused the price of oil to reach a peak in July 2008 close to \$150 per barrel, again served as a reminder of the benefits of a more diversified energy mix.

3. Broadening the global energy mix poses severe challenges, which will require strategic policy measures and significant investments, including in the public sector, to support the development of new energy sources which are currently either too costly, or introduce their own negative externalities, as is the case with some biofuels. In addressing these challenges, policymakers need to develop a holistic and integrated approach to energy security that enables them to evaluate realistically various trade-offs with other development policy objectives.

4. This paper is structured as follows. Chapter I presents a brief overview of the global energy situation with an emphasis on current energy mix and its possible future dynamics. Chapter II highlights the main drivers for developing renewable energy sources and the obstacles in introducing these, particularly in developing countries. Chapter III examines the implications of the evolving energy matrix for energy security. Chapter IV discusses some policy implications and chapter V presents some concluding remarks, including some issues that might serve to focus the deliberations of experts.

I. Global energy situation – historical and current energy mix and future challenges

5. Historically, the global energy system has been dominated by fuels emitting high levels of greenhouse gases. First, firewood was the principal industrial fuel, but its use diminished² after the discovery of coal, which burned more slowly and had a much higher calorific value. From the late 1800s, coal became the fuel of choice, used to power the Industrial Revolution. However, the use of oil expanded rapidly after 1945, supplanting coal in the 1960s as demand for transportation fuels increased. Today, the global energy system is much more complex, with many competing sources of energy and many high-

¹ These sources are termed commercial in the sense that they command a price and users have to pay for them.

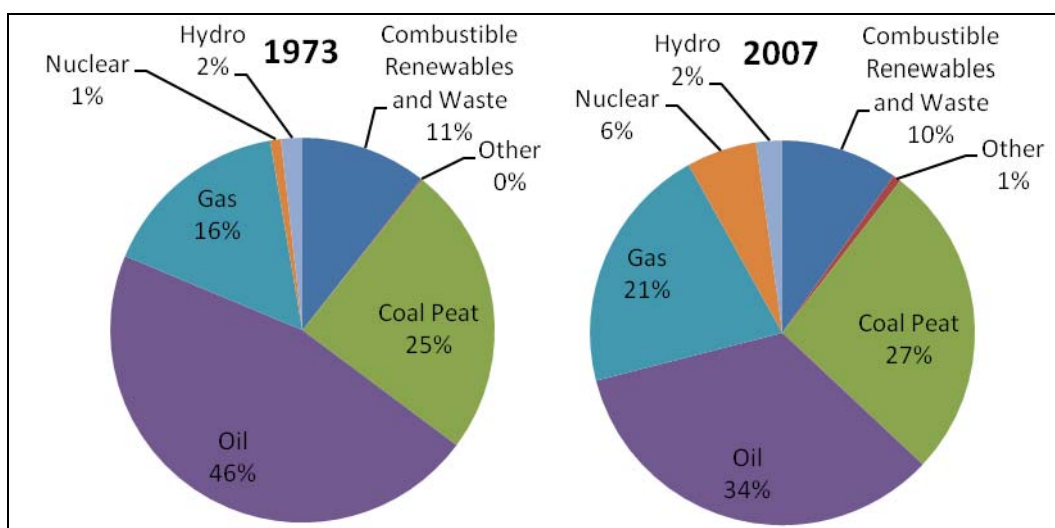
² Firewood is still used in many developing countries; over 2 billion people still rely on this fuel.

quality and convenient energy carriers. Taken together, fossil fuels provide some 80 per cent of global energy needs, while fuelwood, hydropower and nuclear energy provide the rest.

6. Over the past 35 years, natural gas has increased its market share to over one fifth (figure 1) because it is abundant, efficient, has multiple applications and greenhouse gas emissions are much lower than those from coal or oil.³ Renewable energies have seen a similar increase (5 per cent) in market share over this period. However, coal has also made a comeback, despite being a highly polluting fuel, and demand for it could increase if clean coal technology matures.⁴

7. Although conventional crude oil reserves are dwindling, the potential for oil sands, which already form part of total crude oil production, and coal are massive, and could sustain the fossils industry for some time subject to the pace of technological developments, which will in turn influence the costs of extracting oil from oil sands. Figure 1 also reveals that the share of oil in total energy supplies dropped by 10 per cent over more than three decades (1973–2007), but new data on world energy demand between 1990 and 2007 reveals that much of this reduction was between 1973 and 1990, and was therefore most likely due to the two oil crises. Indeed, the fall in share of oil in global energy demand over the period 1990–2007 was only 2.6 per cent –from 36.7 percent to 34.1 percent.⁵

Figure 1. Total primary energy supply, 1973 and 2007



Source: International Energy Agency.⁶

³ http://www.davidsuzuki.org/climate_change/energy/fossilfuels/naturalgas.asp.

⁴ Some of these technologies purify the coal before it burns while others control the burning of coal to minimize emissions of sulfur dioxide, nitrogen oxides and particulates.

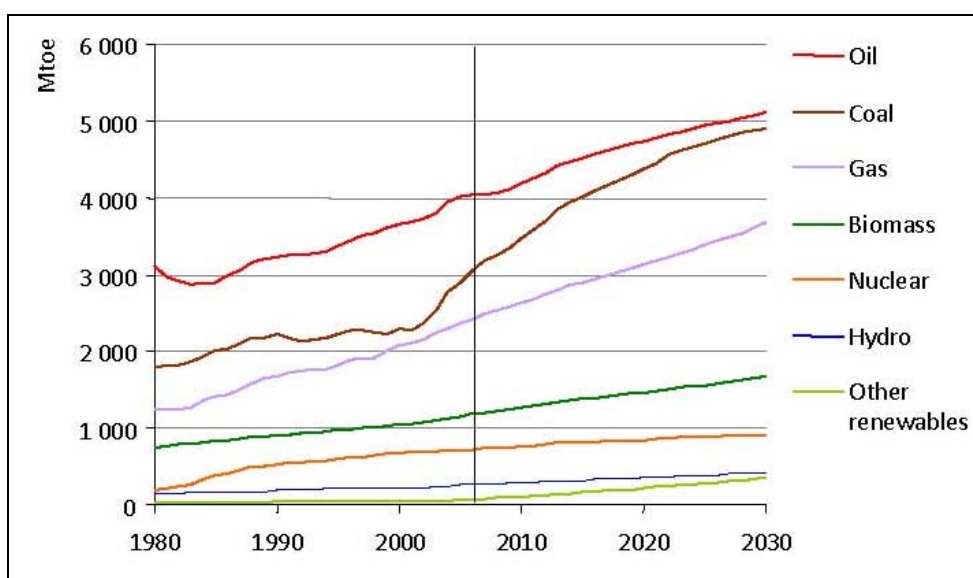
⁵ International Energy Agency (2009). *World Energy Outlook*.

⁶ Combustible renewables and waste comprise solid biomass, liquid biomass, biogas, industrial waste and municipal waste. Biomass is defined as any plant matter used directly as fuel or converted into fuels (e.g. charcoal) or electricity and/or heat. Included here are wood, vegetal waste (including wood waste and crops used for energy production), ethanol, animal materials/wastes and sulphite lyes. Municipal waste comprises wastes produced by the residential, commercial and public service sectors that are collected by local authorities for disposal in a central location for the production of heat and/or power; other includes geothermal, solar, wind, tide/wave/ocean energy, electricity and heat.

8. Total world energy consumption, including renewable energy, is expected to increase by 45 per cent by 2030. An increase of such magnitude from current levels (figure 2), would require an investment of \$25 trillion–\$30 trillion; that is more than \$1 trillion a year for the next 20 years.⁷ International Energy Association (IEA) projections suggest that crude oil will remain the dominant source of energy worldwide, accounting for 77 per cent of the demand increase between 2007 and 2030. That translates in to an increase from around 85 million barrels per day (mb/d) in 2008 to 105 mb/d in 2030. Also, projections suggest 53 a per cent growth in demand for coal between 2007 and 2030, and 42 per cent for natural gas over the same period.⁸

9. The big challenge posed by these projections is that the energy sector accounts for 60 per cent of global greenhouse gas emissions, and is therefore a major factor in global warming. At the same time, cheap and reliable energy is essential for sustained economic growth, improving living standards and eliminating poverty in the developing world. Indeed, a significant part of new investments in the energy sector over the coming decades will take place in the developing world. Consequently, energy is the pivotal issue at the interface of the climate and development challenges.

Figure 2. World primary energy demand



Source: Reference scenario, World Energy Outlook 2008.

What are the options available for a low carbon energy mix?

10. Assuming catch-up growth and continuing rates of urbanization and industrialization, closing the gap between energy supply and energy demand in developing countries will require investments of the order of trillions of dollars, even for low-cost options, such as coal, and certainly well in excess of current energy investments in many developing countries. The bulk of energy infrastructure in developing countries has yet to be built, leaving energy services undersupplied and expensive in many parts of the developing world. Under these circumstances, it may be cheaper and easier to switch a

⁷ Hayward T (2009). Growing economies demanding more energy. *Oil and Gas Journal*. 25 November.

⁸ IEA (2009). World Energy Outlook 2009 FactSheet.

renewable pathway than to retool existing infrastructure.⁹ Still, any big push into low-emissions energy sources is likely to be associated with massive investments, above those that would be involved in a higher-emissions trajectory. Access to affordable and predictable finance, therefore, remains the biggest constraint on shifting to a low emissions, high growth development pathway in many countries.

11. A low-emissions energy mix could be derived from a range of energy sources. These include renewables, such as wind, geothermal, solar, water, and biomass. While some of these are fast becoming conventional sources of energy, at present, the low level of technological development and high costs associated with most of them limit the extent to which they can be incorporated into the global energy matrix on a substantial scale in the foreseeable future.

12. *Wind energy* is one of those currently widely used renewables. Installed capacity has been growing at an annual average rate of 17.1 per cent.¹⁰ In 2008, wind energy generated over 260 terawatt-hours (tWh) of clean power (the equivalent of more than 1.5 per cent of the global electricity consumption) in more than 70 countries.¹¹

13. *Geothermal energy*, originating from beneath the Earth's surface, is exploited only in a few places. The steam from geothermal wells is used to generate electricity and heating. Geothermal is a fast-growing renewable energy (20 per cent annually). Analysis suggests that by 2010 there could be as many as 46 countries using geothermal energy, generating as much energy as 27 coal-fired power plants.¹² Developing countries are the main producers, with 10 countries among the top 15 worldwide. In 2007, geothermal contributed only 0.4 per cent of total global energy supply.¹³

14. *Solar energy* is harnessed from the sun using photovoltaic cells for electricity production or through solar heating collectors to heat water. It is an appropriate form of energy for many rural dwellers, who are often marginalized from grid systems because of the huge costs involved. The photovoltaic industry's growth has been aided by subsidies mainly in temperate developed countries such as Germany and Japan where installed capacity is 42 per cent and 21 per cent respectively of the world total.¹⁴ Forecasts suggest that solar electricity could be cheaper than electricity from conventional sources by 2015 due to two main factors – ongoing developments in Photovoltaic technology and rising price of fossil fuels.

15. The potential for *hydro energy* is huge but less than a third of the world's hydro resources have been developed due to the environmental sensitivities and the mammoth task in resettling communities that are affected in the process of damming rivers. In 2007, hydro energy accounted for just 2 per cent of global energy supplies, virtually unchanged from 1973 (figure 2). Other forms of kinetic energy, including wave and tidal power, are at an early stage of development and are therefore not part of the global energy mix.

⁹ A global renewable energy push will still have to be led by advanced countries. For an assessment of that challenge, see Jacobson M and Delucchi A (2009). A plan to power 100 per cent of the planet with renewables. Scientific American Magazine. November.

¹⁰ Global Wind Energy Council:
[http://www.gwec.net/index.php?id=30&no_cache=1&tx_ttnews\[tt_news\]=232&tx_ttnews\[backPid\]=4&cHash=c11503e4d8](http://www.gwec.net/index.php?id=30&no_cache=1&tx_ttnews[tt_news]=232&tx_ttnews[backPid]=4&cHash=c11503e4d8).

¹¹ World Wind Energy Association report 2008:
http://www.wwindea.org/home/images/stories/worldwindenergyreport2008_s.pdf.

¹² This will almost double the number of countries harnessing heat from the Earth in the first half of 2008. Dorn JG (2008). Geothermal power generation nearing eruption. Earth Policy Institute, 19 August.

¹³ <http://kn.theiet.org/sustainability/renewable-energy.cfm>.

¹⁴ Keller A and Ploss T (2009). Solar at the crossroads. ICIS Chemical Business 3–16 August.

16. Most of *biomass energy* is generated from plant material. Developing countries are the biggest consumers of biomass with the traditional biofuels such as wood accounting for about a third of all energy consumed in these countries. However, these are not efficient sources. Many sub-Saharan African countries depend on biomass for up to 90 per cent of their primary energy consumption.

17. Biofuels for transport comprise ethanol and biodiesel.¹⁵ Ethanol is derived from crops such as corn, sorghum, barley or sugarcane while biodiesel is derived from vegetable and animal fat. Production of these fuels is heavily concentrated in a few countries. Brazil and the United States together accounted for more than 87 per cent of ethanol production in 2008 (table 1). Most of the ethanol produced in the United States uses corn as its feedstock whereas Brazil relies on cheap sugarcane. In European Union (EU) countries such as Germany, France, and Italy, the dominant product is biodiesel. Together, these countries produced more than 35 per cent of global biodiesel in 2008. Fuels derived from palm oil, jatropha and other cellulosic biofuels have also become commercialized, but the rate of market penetration has been slow due to the high costs involved and new and underdeveloped technology. These two factors also restrict the share of cellulosic biofuels in the global energy mix. For example, studies suggest that it requires 3.3 gallons of oil to produce one gallon of ethanol from cellulosic material.¹⁶ Overall, the biofuel output of the top five countries accounts for over 85 per cent of total global production. However, biofuels have not had a significant impact on the energy mix because global production is still relatively too small and the land requirements are too high. World total biofuels production in 2008 reached 1.5 mbd (compared to 85 mbd of crude oil).

Table 1
World liquid biofuels production, 2008

	Ethanol		Biodiesel		Total biofuels	
	Share (%)		Share (%)		Share (%)	
United States	50.1	Germany	19.1	United States	43.8	
Brazil	37.5	United States	17.5	Brazil	31.6	
China	2.7	France	12.3	Germany	4.3	
France	1.2	Brazil	7.0	France	3.3	
Germany	0.8	Italy	4.5	China	2.5	
Sum of top 5	92.3	Sum of top 5	60.4	Sum of top 5	85.5	
Others	7.7	Others	39.6	Others	14.5	
Total World	100.0	Total World	100.0	Total World	100.0	

Source: United States Department of Energy, International Energy Database.

¹⁵ Biofuels is often defined to include biogas (methane) generated from landfills, sewage sludge, animal manure and other farm waste materials. This document focuses only on liquid biofuels used primarily as transportation fuels.

¹⁶ Pimentel D (2009). Corn ethanol as energy: the case against US production subsidies. *Harvard International Review*. Cambridge: Summer. Vol. 31, No. 2: 50.

II. Drivers of the future energy matrix and the challenges facing developing countries

18. A variety of factors are driving the evolution of the future energy mix. These are generally related to availability of resources, production cost, environmental benefits (and costs), energy security and technological developments. As fossil fuels are non-renewable energy sources, their contribution to the future energy matrix will partly depend on how soon known reserves are depleted or on the costs of extraction. Many experts believe production has peaked in certain regions and has started to decline. British Petroleum (BP) estimates show that at current rates of production oil reserves will be depleted in less than 50 years, natural gas in 60 years and Coal in 122 years (table 2). Although new discoveries are being made, these lag behind of the increase in demand and often present technological challenges which contribute to rising costs of production.

Table 2
Global hydrocarbon reserves and production, 2008

	Reserves	Production	R/P (years)
Oil ^a	195.3 x 10 ⁹ tons	3.928 x 10 ⁹ tons	49.7
Natural gas	185.0 x 10 ¹² m ³	3.066 x 10 ¹² m ³	60.3
Coal	826.0 x 10 ⁹ tons	6.770 x 10 ⁹ tons	122.0

^a Includes reserves of Canadian oil sands.

Source: BP Statistical Review of World Energy, June 2009.

19. The development of other fuels in the future energy mix is being largely driven by the rising cost of fossil fuels. In power generation, for example, the best potential to maintain electricity supply without excessive price increases comes from using nuclear fuel.¹⁷ However, considering the problem of nuclear waste disposal, hydro energy is probably the best alternative from a cost point of view, although here too there are some limitations, as discussed earlier.

20. The shift away from fossil fuels to renewables is also driven by the environmental impact resulting from the burning of these fuels. The associated link of greenhouse gas emissions with climate change has raised concerns to stabilize the fast-rising levels of carbon dioxide to a natural range of between 180 and 300 parts per million (ppm) as compared to its current levels over 400 ppm.

21. Improving energy and national security by shifting to greater reliance on local power sources has also played an important role in the rise of renewables. Twelve countries control nearly 80 per cent of the world's oil reserves and more than 40 per cent of oil global production.¹⁸ This has proven to have adverse effects on the world markets when there is a supply shock, thus making it even more necessary to look for alternative sources of energy. In the transportation sector, where most crude oil is consumed, multiple fuel options, ranging biofuels to fuel-cell and battery-powered vehicles, have been making inroads into the energy matrix. The rational is to diversify into other domestic fuel types to stabilize prices at the pumps and at the same time meet carbon dioxide emissions limits.

¹⁷ The Economics of Nuclear Power: <http://www.world-nuclear.org/info/inf02.html>.

¹⁸ <http://www.opec.org/home/PowerPoint/Reserves/OPECshareWorldcrude.htm>.

22. New technologies such as carbon capture and sequestration¹⁹ would prolong the future use of high-polluting fuels such as coal, which is abundant in supply, cheap and widely found across the world. Other technologies in the renewable sector including wind, solar, advanced power grids and hydrogen. The more widespread use of these technologies should lower the costs of cleaner energy, though this is still happening too slowly to meet climate objectives. The promise of green jobs from manufacturing, installation and maintenance in an evolving industry (of renewable energy projects) would also likely play a role in modifying the future energy mix. According to estimates, more jobs are created per unit of electricity generated from the renewable energy industry than from fossil fuels; opportunities for job creation are also expected to be high in both the agricultural and production sectors.²⁰

Factors hindering the deeper integration of renewables into the global energy matrix

1. Costs and financing

23. A big push into renewable energies poses serious challenges to policymakers in developed and, particularly, in developing countries. One hundred kWh per capita per day can be used as the dividing line between energy poverty and energy sufficiency. Up to this level, there is a very strong correlation between increased energy consumption and development goals. Such levels of energy consumption will, however, be out of reach of most poor countries unless the price of energy services is significantly below current levels. If energy costs 10 cents per kWh, then \$10 per day would be needed to consume the requisite levels of energy services. This is not just a problem for the bottom billion; spending \$10 per day on energy services would exhaust the per capita income of several countries such as Angola, Ecuador and the former Yugoslav Republic of Macedonia.

24. Today, coal and perhaps large hydro are the only sources that generate energy at sufficiently low costs. Consequently, while it seems clear that the only way to achieve development and climate goals is with an energy infrastructure built around renewable energy, cleaner coal, and carbon capture and storage, these are currently costly options. Experts suggest that the world would need to invest at least an extra \$500 billion annually in these clean energy sources, an increase of 40 per cent over what might have been invested in the energy industry in a “business-as-usual” scenario.²¹

25. What is needed is a strategy that will bring a significant and timely reduction in the cost of renewable energy services. A massive public investment push, coupled in the short term with appropriate subsidies to offset high initial prices, will likely be at the heart of such a strategy. If targeted at the most promising technology options (e.g. solar and wind), such a strategy could trigger an early cost write-down through innovation and scale economies, giving the private sector clear and credible signals, and encouraging energy efficiency.

¹⁹ This is a broad term used to describe a number of technologies that can be used to capture CO₂ from point sources, such as power plants and other industrial facilities, compress it, transport it mainly by pipeline to suitable locations, and inject it into deep subsurface geological formations for indefinite isolation from the atmosphere.

²⁰ Kammen D, Kapadia K and Fripp M (2004). Putting renewables to work: how many jobs can the clean energy industry generate? 13 April.
http://www.unep.org/civil_society/GCSF9/pdfs/karmen-energy-jobs.pdf.

²¹ UNDESA (2009). *World Economic and Social Survey, 2009: Promoting Development, Saving the Planet*. United Nations, New York; Crooks E., Down to business, Financial Times, 3 December.

26. The main constraint on adopting this big push in many developing countries is access to predictable and affordable finance. In line with their historical responsibilities, as well as commitments made in Kyoto and Bali, the onus is on advanced country governments to fund a big push in to clean energy sources in the developing world. So far, the resources dedicated to climate mitigation in developing countries have been very small and poorly targeted. Further research on the scale of required resources and the best mechanisms to raise and channel those resources is urgently needed.

2. Technology and technical capacity

27. The potential of renewable sources of energy will require overcoming a number of technological hurdles. Before wind and solar power can be used more widely, for example, it will be necessary to devise more efficient electrical storage devices that could store energy when the wind and sun are strong and release it at night or when the weather is cloudy or windless. More efficient transmission systems are also needed to carry electricity from areas of greatest reliable wind and sunshine to areas of greatest demand. Likewise, new methods are needed to convert waste plant matter into ethanol. Other sources of energy will also require rapid technological advancement.

28. Cleaner fuels require new technologies, many of which are still protected by intellectual property law. This often acts as a barrier to transfer of technology to developing countries. According to a study by Chatham House, meeting the climate change goals will require that the diffusion time for clean technologies globally, which normally takes between two to three decades, be halved by 2025.²² However, questions remain on the competitiveness of companies who invented these technologies, e.g. how their investment in those technologies would be compensated for if they are to be transferred. Furthermore, a lack of appropriate technical capacity for the maintenance of renewable energy systems has hampered progress in deployment of renewable energy technologies in developing countries.

29. An operational climate technology programme and related global research and development (R&D) fund, supported by a secretariat and various panels of experts, is needed to examine the various dimensions of the technology challenge relating to renewables, particularly in developing countries. In addition to intellectual property issues, modalities for access to publicly funded technologies by developing country firms need to be explored.

3. Concerns related to food security

30. Until 2000, food prices were declining, with record harvests and the draw-down of food stocks. During the same period, public and private investment in agriculture (especially in staple food production) was declining with a detrimental impact on productivity growth in the agricultural sector in many developing countries. In 2007, rapid increases in oil prices not only increased fertilizer and other food production costs, but also provided a climate favourable to an expansion of biofuel crop production, largely from coarse grains and vegetable oil crops. The high oil prices, in combination with other factors, triggered steep rises in food prices. According to the Food and Agriculture Organization of the United Nations, the food crisis has added about 100 million people to the ranks of the food insecure.²³

²² Lee B, Ilev I and Preston F (2009). Who owns our low carbon future? Intellectual property and energy technologies, A Chatham House Report. September.

²³ See also United Nations (2009). World Economic Situation and Prospects: 26.

31. The rise in food prices and food insecurity is also linked to policy measures that propagate the use of biofuels. The EU, United States, India, Brazil and China have all set targets to increase biofuels. For instance, the EU has declared that, by 2010, 5.75 per cent of all gasoline sold to motorists in Europe must stem from biofuel production. New legislation under discussion would aim to raise the blending rate of gasoline to 10 per cent by 2020.²⁴ The United States Energy Bill introduced in 2007 put targets that nearly doubled utilization levels of biofuels in 2008 from the previous year, and rising to 36 billion gallons by 2022.²⁵ These policies have contributed to boosting ethanol production in the US by 41.3 percent in 2008 and biodiesel in the EU by 35.7 percent.²⁶ The European Union is currently responsible for over 50 per cent of global biodiesel production and the main feedstock used comes from rapeseed oil while palm oil is also imported to make up the shortfalls. To meet this increased demand, exporters of palm oil are increasing cultivation, which requires a lot of land, in order to rake in the economic benefits often at the expense of arable land for food.

32. The production of ethanol and biodiesel has far-reaching effects on food security. The first is on the actual availability of food. It has been estimated that 22 pounds of corn grain is required to produce 1 gallon of ethanol. Thus, a special utility vehicle will require a total of 660 pounds of corn or food to fill its tank, enough to feed two people in a developing country for the whole year.²⁷ Subsidies for biofuel production in developed countries have encouraged farmers to shift from growing wheat and other grains, thus contributing to a shortage of food and price distortions on world food markets.

33. Secondly, there has been a decrease in the access to food as subsidies on biofuel crops act as an implicit tax on staple foods on which the poor depend the most. More competition in the demand for agricultural inputs, energy and labour has also led to increased world prices of other food crops. Farmers' focus on maize production has also led to increased demand for other crops to substitute for maize consumption. This process has in turn generated an upward pressure on prices.

34. Thirdly, in addition to the impact of ethanol production on competition for land and water in many developing countries, there are also concerns regarding its environmental impact. Some estimates show that, by 2020, an additional 22 million hectares of arable land in developing countries will be needed to cope with the increased demand generated by biofuels.²⁸ On the environmental front, the high demand for corn in biofuel production and the economic benefits of growing it have forced production to be continuous year round without alternating the crops. This according to experts has dramatically increased soil erosion on arable land from 5 tons per hectare per year to 17 tons per hectare per year, degrading valuable cropland. The abandoning of crop rotation with other crops has also increased the weed and disease problems, leading to the high use of insecticides. Experts point out that if farmers grew their corn in rotation with other crops, for example wheat, they could abandon the use of insecticides and also increase corn yields.²⁹ Furthermore, the

²⁴ UNCTAD (2008). Addressing the global food crisis: Key trade, investment and commodity policies in ensuring sustainable food security and alleviating poverty: 9.

²⁵ http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_bills&docid=f:h6eah.txt.pdf.

²⁶ <http://www.ebb-eu.org/stats.php>.

²⁷ Pimentel D (2009). Corn ethanol as energy: the case against US production subsidies. Harvard International Review. Cambridge: Summer. Vol. 31. No. 2: 50, 3.

²⁸ International Institute for Applied Systems Analysis (2009). Biofuels and food security: implications of an accelerated biofuels production. Vienna.

²⁹ Ibid.

leaching of nitrogen fertilizers and pesticides from cornfields into water bodies can also contribute to a severe reduction in fish stocks and shrimp production.³⁰

III. Implications of the evolving energy matrix on energy security

35. Access to sustainable cheap energy is essential to the functioning of modern economies. However, limited supplies of non-renewable energy and uneven distribution of reserves among countries have prompted competition over energy resources, particularly in fossil fuels. Rising costs of fossil fuels and environmental concerns have thus intensified the need to diversify from fossil fuels to alternative sources of energy in order to secure energy supplies.

36. “Energy security” covers a broad range of issues, from uninterrupted oil, natural gas and LNG supplies to the protection of energy infrastructures from terrorist attacks. Historically, the concept was applied to consuming countries but it has evolved in recent years to incorporate the responsibility of both consumers and producers. For example, factors such as political unrest and violence in several oil-producing countries, the increased cooperation between oil-producing and oil-consuming countries, multinational oil companies’ investment in the oil-producing countries, uncertainty over the available reserves, and the possibility of an oil production peak in some oil producing countries have all raised concerns about the uninterrupted flow of cheap energy to consumers.³¹ Maintaining security of demand has also been highlighted as a necessary factor to facilitate the supply of energy. It is therefore important to address both the security of supply and the security demand as a means to attaining energy security. A simple method, generally accepted in measuring energy security, involves assessing whether supplies are available, accessible, affordable and acceptable. Precise indicators have yet to be designed as the notion of energy security is highly contextual.

Some key characteristics of energy security³²

1. Energy prices

37. Energy security has an economic dimension that is linked to the price level and market behaviour. The provision of affordable energy to the consumer is dependent on the cost of production/generation, transportation/transmission and distribution. The interruption of supply networks can negatively impact on prices and create economic challenges for countries over-reliant on one energy source. Sustained price rises and short-term spikes in oil, gas or electricity can trigger inflation or recession. Energy (in particular oil³³ and gas) prices are among the most volatile of all commodities.

38. The recent volatility and a record oil price level of \$147 per barrel (bbl) in July 2008 are stark reminders of the importance of alternative sources of energy in the future energy mix. Development of renewable energy is seen as a necessary step in addressing fluctuating prices and the economic instability that comes with dependence upon fossil fuels. Price volatility is expected to continue due to supply concerns in the face of rising demand. The International Energy Agency has indicated that oil prices could go back up to an average of

³⁰ Ibid.

³¹ Alhajji AF (2007). What is energy security? Definitions and concepts. MEES Vol. L No. 45. 5 November.

³² Due to space constraints, global energy security is examined in this paper from the standpoint of the security of supply.

³³ Murphy C (2009). Why do oil prices swing so wildly? MoneyWatch.com. 1 September.

\$100/bbl between now and 2015, and could average more than \$120/bbl by 2030. Sustained high oil price levels are a driver for the development of alternative sources of energy as some analysts consider oil trading at above \$90/bbl to be the threshold to render the development of renewable energy cost-effective.

2. Energy independence

39. Understanding energy independence is necessary for formulating an effective energy security policy. To achieve “oil independence”, a nation must reach a state in which its economic, military or foreign policies are not subject to the restraining or directing influence of oil producers. This definition captures the essential idea but it is not measurable. A measurable definition needs to reflect the uncertainty about future oil market conditions and include a quantitative statement³⁴ of how much the potential costs of oil dependence must be reduced.

40. Among the measures taken to achieve energy independence is fuel substitution, a diversification in the uses of fuels and fuel transformation that can meet demand even when conventional supplies may be affected, and increase efficiency. (See box 1.)

41. For countries exposed by over-reliance on one energy source, *energy efficiency* has been used as a means to reduce the dependency on that single source. In this paper, “energy efficiency” is defined as the ratio of the amount of energy services provided to the amount of energy consumed.³⁵ Thus, using less energy to provide the same level of energy services or obtaining more energy services from the same energy input is defined as an efficiency gain. Energy efficiency may be improved by reducing energy consumption. This trend has already started in many developed countries where increasing flexibility of economies and improvements in energy efficiency (including energy conservation measures in the industry value chain) have lowered energy intensity-to-GDP ratios. As a result, the share of oil in the energy matrix of these countries relative to GDP has decreased.

Box 1. Policy measures towards energy independence: the case of the world two main oil consuming countries – US and China

United States

United States energy security is largely based on building up oil and gas supplies by keeping its proven oil and gas resources underground while relying on imports, and building strategic petroleum reserves (SPR) as well as diversifying product and geography sources. (As of August 2009, the United States SPR held 724 million barrels of crude oil, while government-controlled petroleum stocks in the OECD countries stood at 1.56 billion barrels.) In this respect, the development of local renewable sources such as bioethanol, wind energy is encouraged. Technological breakthroughs are used as means to foster the diversification of product sources

³⁴ For example, “the annual economic costs of oil dependence will be less than 1 per cent of United States GDP, with 95 per cent probability, by 2030.” *Source*: Greene DL and Leiby PN (2007). Oil independence: realistic goal or empty slogan? Oak Ridge National Laboratory, March.

³⁵ The economy’s increasing flexibility and improvements in energy efficiency explain the decrease of energy intensity-to-GDP ratios. The energy intensity of aggregate world output is lower than it was in the 1970s: in 1980, the United States consumed about 17 mbd to produce GDP worth \$45.2 trillion (in 2000 prices). By 2005, oil consumption reached 20.7 mbd, but GDP had more than doubled to \$110.1 trillion.

such as clean coal technologies or solar storage. Geographic diversification of supplies away from unstable regions contributes to its strategy. African States, particularly West African producers, have been identified as an ideal source of United States oil imports (imports from Africa are expected to increase from 18 percent in 2007 to 25 percent by 2015) because transporting oil from Africa is cheaper than shipping oil from the Middle East, and protecting onshore and offshore installations and reserves is easier. In addition, Africa offers a good climate for private investors to create an ethanol industry to supply the United States with an alternative energy source which would at the same time diversify African economies.

China

The rapid rise of China's energy consumption to fuel its economic growth and meet the needs of its large population, as well as maintain economic stability, has prompted its need to build closer ties to energy-producing countries, including the acquisition of interests in exploration and production in these countries. China's strategy to reduce future dependence on oil imports also includes fostering clean coal technologies to make full use of its large reserves, estimated to be about 12 per cent of world reserves.

China became a net oil importer in 1993, and a decade later was the second-largest consuming and third-largest importing nation. IEA estimates that, by 2020, China oil imports could be double its current imports. And most of this new demand will be met by seaborne oil shipments, raising concerns about oil security.

Measures to achieve the government goals for energy security and energy efficiency also include the establishment of special funds to encourage State-owned oil companies to expand upstream and downstream investments abroad (through takeovers and mergers of resource companies abroad) as well as augment crude and oil product stockpiles.

3. Energy Cooperation and cross-border investments

Institutional arrangements for energy cooperation

42. Several institutions, such as IEA and the International Renewable Energy Agency (IRENA), and various instruments have been developed to address energy security through regional and international cooperation. Two examples of these are PetroCaribe Initiative³⁶ and the Energy Charter Treaty. The treaty is a political initiative launched in Europe in the early 1990s for developing mutually beneficial energy cooperation among the States of Eurasia. It is a legally binding multilateral instrument meant to provide for a more balanced and efficient framework for international cooperation than is offered by bilateral agreements alone or by non-legislative instruments. The treaty therefore plays an important role as part of an international effort to build a legal foundation for energy security, based

³⁶ The PetroCaribe Initiative is discussed in TD/B/C.I/MEM.2/4.

on the principles of open, competitive markets and sustainable development. It is underscored by three broad interconnected goals: increasing European-wide energy security, enhancing sustainability and fostering competition in Europe's internal energy market.

43. The Energy Charter Treaty and the EU–Russian Federation Energy Dialogue are institutional mechanisms collectively used by the EU to address energy relations with suppliers. However, the effectiveness of the mechanism remains to be seen and the European Commission is seeking to strengthen multilateral mechanisms, including the Energy Charter, to better coordinate global energy policy among consumer, transit, and producer nations.

Attaining energy security via cross border investments

44. The EU³⁷ currently relies on the Russian Federation for a quarter of its total gas supplies and 80 per cent of that is piped through Ukraine. Of the bloc's 27 member States, 7 are almost totally dependent on Russian Federation gas. However, disputes between the Russian Federation and its neighbours over gas prices have led to occasional shutdowns of supplies to much of Europe for weeks, causing severe shortages for businesses and millions of households. This concern with the Russian Federation's reliability as a source for import is compounded by rapidly growing domestic need for natural gas in the Russian Federation.

45. To address its import dependency, Europe's policymakers are considering a number of major infrastructure projects which aim at diversifying natural gas supply routes (by reducing transit risks) and sources, thereby raising the energy security of the entire European continent. Three projects are illustrative of this EU strategy. The first two are the South Stream and North Stream pipeline projects that will provide new export routes for Russian Federation gas, while the third, Nabucco, is meant to be a major alternative source to Russian Federation gas (see box 2).

Box 2. Europe's infrastructure projects to improve energy security

The South Stream project would go from the Russian Federation's south coast under the Black Sea to Bulgaria, eventually ending in Italy. Its major objective is meeting the EU additional demand for natural gas by delivering 63 billion cubic meters per annum to Europe.

The North Stream project is intended to deliver up to 55 billion cubic metres of gas every year from the Russian Federation port of Vyborg to the northern coast of Germany through a pipeline of 1,200 km that will run under the Baltic Sea. This is enough to supply more than 26 million households and total investment in the offshore pipeline is projected at 7.4 billion euros. North Stream is designed to circumvent regional politics by cutting out transit countries. It could mark a significant change in Europe's energy security and a new benchmark in EU-Russian Federation cooperation.

³⁷ The EU currently imports more than 40 per cent of its natural gas needs, with the major suppliers being the Russian Federation, Norway and Algeria. It is expected by the European Commission that the EU's dependency will rapidly increase in the coming decades. This import dependency will rise from 40 per cent to 55 per cent in 2010, to 67 per cent in 2020, and to 81 per cent in 2030, according to the Europe Energy Outlook 2020. Source:

http://ec.europa.eu/dgs/energy_transport/figures_archive/energy_outlook_2020/index_en.htm.

The Nabucco pipeline project would bring gas from Central Asia and the Middle East to Europe, bypassing the Russian Federation completely. It is planned to take a 3,300-km overland route through Turkey, Bulgaria, Romania, Hungary and Austria and to deliver 31 billion cubic metres of gas a year to Europe. Estimated investment costs amount to approximately 10 billion euros. The political jigsaw is complex due to the high number of countries involved and the uncertainty over the source of gas (availability of appropriate resource base) to fill the pipeline.

Apart from diversification of routes and implementation of joint projects to construct new offshore pipeline systems, another vital element of the new architecture of the European energy security is the creation of Trans-European Energy Networks, which focus on regional formation and other initiatives, such as the Atlantic Energy Security Initiative, that seek to create a collaborative network of public and private actors involved in developing and supporting energy development in the Atlantic basin and beyond.

Sources: <http://south-stream.info/>; <http://www.nord-stream.com/en/>; and <http://www.nabucco-pipeline.com/company/about-us/index.html>

46. The composition of energy supplies, in terms of types of energy as well as geographic sources, will inevitably change in coming years. The change will be driven by policies designed to mitigate climate change and enhance energy security. The pace of the change will also be influenced by macroeconomic developments and by advances in technology regarding energy end-use efficiency, carbon capture and sequestration, alternative energy sources, and the discovery and production of hydrocarbons. In addition, the pace of the change will be affected by government policies in the areas of international trade and cross-border investments.

47. Most projections foresee, in the next two decades, a declining but still dominant share for hydrocarbons, and an increasing share of renewables from their present relatively minor place in the energy matrix. These changes will have important implications for both energy exporting and energy importing countries.

IV. Policy options for developing a low-carbon future energy mix

48. A broad range of options can be deployed to support the market development of renewable energies and increase their share in the world energy matrix. However, the costs of building generating capacity for renewable energy can only be met through a big investment push. Much of this will eventually have to be undertaken by the private sector, but it is likely that, in the initial stages, the public sector will play a very significant role, including with financial support from the international community. Appropriate policies may also be required to increase the efficiency of the renewable technologies if they are to have a deeper market penetration.

49. Fiscal and financial incentives have been used by several countries to reduce the burden of huge capital costs of renewable projects. These types of incentives are not limited to businesses but are also aimed to help consumers to purchase renewable energy systems. Other types of incentives such as finance arrangements, where the government assumes risk or provides low interest loans as well as tax exemptions, and production tax credits have

contributed to the development and production of renewable energy. Developing countries have also designed incentive packages including tax reductions and other fiscal and financial incentives to attract foreign direct investment into their renewable energy sector.³⁸

50. Energy generation using renewable resources can also be targeted. In this instance, power generators are guaranteed prices by governments for using renewable energy sources. This principle, which was first used in the United States, has been adopted by a number of OECD countries. Utilities are required to purchase power from these renewable energy developers at a premium and are paid the cost that they would have incurred by generating or otherwise supplying the power itself. However, the prices set by utilities and state regulatory commissions have sometimes been too low to support new project development.³⁹ A global feed-in tariff programme could provide guaranteed purchase prices to producers of renewable energy in developing countries over the next two decades.⁴⁰

51. Policies to encourage alternative energy technologies have typically overlooked the challenges of deployment. On the one hand, government policies have supported R&D efforts and pilot-plant construction while, on the other hand, funding is often available from public or private sources for the construction of commercial facilities. In between, however, private developers of alternative energy infrastructure must finance their applications for construction permits, and this can be a long and expensive process involving considerable risk. Government policies could ease this process by reducing and standardizing the number of approvals required.

52. Another policy instrument commonly used in developed countries is the quota system, in which suppliers of electricity or liquid fuel are obliged to provide a fixed quantity or a percentage of their supply from renewable energy resources. In 2002, the United Kingdom introduced a policy of Renewables Obligation, which required electricity suppliers to produce 3 per cent of supplies from renewable sources. Since its introduction, it has stimulated growth in this sector: capacity has more than doubled, and a project pipeline of more than 11 gigawatts is in place across the United Kingdom.⁴¹ The Government has also put in place targets under the Renewable Transport Fuel Obligation, where road transport fuel suppliers are required to ensure that, by 2010/2011, 5 per cent of total road transport fuel supply in the United Kingdom is made up of renewable fuels. In many countries, targets have been introduced to phase in renewable energies, sometimes with a penalty for non-compliance.

53. Multilateral cooperation in reducing greenhouse gases such as the clean development mechanism as defined in the Kyoto protocol article 12 can be employed in introducing new energy sources into the global energy matrix. The mechanism offers a real possibility for shifting the energy mix of developing countries in line with the future trends in energy production and consumption, while giving industrialized countries some flexibility in meeting emission targets. However, reforms are needed if the mechanism is to significantly scale-up transfers, in particular its current project-based approach will need to give way to more of a programmatic and policy focus.

54. Stable demand from customers encouraged to purchase renewable energy can boost the share of renewable energies in the future energy matrix. This can be done through

³⁸ http://www.nri.org/projects/biomass/conference_papers/policy_material_section_3.pdf.

³⁹ IEA.

⁴⁰ See UNDESA (2009), op cit.

⁴¹ Department of energy and climate change, United Kingdom:
http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/policy/renew_obs/r_ew_obs.aspx

consumer grants or rebates and through tax incentives to suppliers to increase capacity, as well as to consumers to change their type of energy consumption.

55. Some of these policies have, however, raised concerns. Policies to promote specific technologies typically define the targeted goals too narrowly. The achievement of intended environmental or supply-diversification improvements in the most efficient manner requires flexibility in the choice of technology. Policies that establish mandatory emissions levels, for example, without specifying the technology to be used (e.g. corporate average fuel-efficiency levels for vehicle fleets), perhaps have the greatest chance of achieving their objectives at the lowest possible cost. Forcing technology that is not mature on manufacturers to meet emission levels adds to the costs of research, development and commercialization, whereas if available technology is utilized, emission levels can be met with demonstrated technology. As a result, the technical and financial risks are significantly decreased in following mature technologies.

56. With particular regard to biofuels, governments should be cautious in providing incentives that merely divert food crops into first-generation biofuel production.⁴² The recent IEA report on the transition from first to second generation biofuels suggests that the production of biofuels based on non-food biomass will avoid problems related to the biofuel derived from food crops, and in the long term may prove to be a less costly alternative.⁴³

57. Decision makers will also need to investigate more carefully the link between energy policies and other development policies, and decide how energy security is linked to economic, environmental, foreign and social goals. It is very clear that every nation has to adopt a holistic approach to its energy needs and security, given that difficult policy trade-offs and contradictions are mounting, the more so with the growing interdependence of development and climate objectives.

V. Concluding remarks

58. Access to commercial energy is fundamental to development and the eradication of poverty in the developing world. However, this form of energy, particularly fossil fuels, is also responsible for greenhouse gas emissions, which threaten the stability of the climate system. It is therefore imperative to introduce low-carbon energy sources in the national and global energy mix, while shedding the dependence on fossil fuels so that countries are able to attain energy security without jeopardizing the efforts made in attaining food security. Renewable energy projects, particularly, wind and solar, offer compelling environmental advantages when compared to fossil fuel energies in power generation, including little or no conventional pollutant and greenhouse gas emissions. Nevertheless, such renewable energy projects face serious challenges competing with conventional fossil fuel-fired power projects, as technologies are still evolving and costs have remained relatively high.

59. In accordance with paragraphs 91 and 98 of the Accra Accord, the expert meeting may wish to consider opportunities for the diversification of the energy matrix, including renewable energies, while being aware of countries' needs to ensure a proper balance between food security and energy concerns; and make recommendations on the immediate actions needed to be taken to cope with their development challenges as energy prices rise.

⁴² OECD-FAO Agricultural Outlook 2008–2017: 30.

⁴³ OECD-IEA (2008). From 1st to 2nd generation biofuel technologies: an overview of current industry and R&D activities. November.

60. Accordingly, the expert meeting may wish to take up the following issues:
- (a) What types of measures and support have been successful in helping developing countries take advantage of opportunities for diversifying energy supplies?
 - (b) What support measures are needed at the regional and international levels to help these countries enhance access to renewable energies?
 - (c) How can subsidies be phased in if they have to be used to promote alternative energies?
 - (d) How can the problems of food security be addressed at the national, regional and international levels – including the levels of aid required to meet such needs – with regional initiatives such as regional food reserves and national safety nets?
 - (e) How can the issues of energy security be addressed for developing countries? What measures are needed to help cushion energy price shocks for developing countries?
 - (f) What are the viable options for the diversification of energy resources to attain energy security?
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