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Approaches to the Development of Renewable and Clean Energy in Brazil, China, Egypt India and South Africa: Lessons of Emerging Countries

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Abstract

The populous, fast growing emerging economies of Brazil, China, Egypt, India and South Africa face daunting challenges on the energy, environment and climate change fronts. These five countries accounted for 42 per cent of the global population in 2008, but had only 26 per cent of global energy supply. Brazil, China, Egypt and India have per capita incomes below the global average even in PPP terms; only South Africa has a higher income than the global average. Per capita income grew between 1990 and 2008 at 9.1 per cent in China, 4.7 per cent in India and 2.5 per cent in Egypt. However, in Brazil and South Africa, per capita incomes grew at below the world average. CO_2 emissions per unit of energy are lowest for Brazil, way below the global average, reflecting the significant role of hydropower and ethanol in its energy use. China's energy mix is more CO_2 emitting than the global average. The other three countries are around the global average. There is pressure on them to contain their emissions. For this reason, the use of renewable energy sources becomes attractive. This will also help these countries reduce their dependence on energy imports. The paper synthesizes the progress and policies in promoting renewable and clean energy in these counties based on country case studies.

JEL Classification*: Q41, Q42, Q48.*
Keywords*: Energy, renewable sources, energy policy.*

Executive summary

The Background

The populous, fast growing emerging economies of Brazil, China, Egypt, India and South Africa face daunting challenges on the energy, environment and climate change fronts. These five countries accounted for 42 per cent of the global population in 2008, but had only 26 per cent of global energy supply. Brazil, China, Egypt and India have per capita incomes below the global average even in PPP terms; only South Africa has a higher income than the global average. Per capita income grew between 1990 and 2008 at 9.1 per cent in China, 4.7 per cent in India and 2.5 per cent in Egypt. However, in Brazil and South Africa, per capita incomes grew at below the world average. Energy consumption in these countries is growing. With economic growth and higher populations, the demand for energy would be even higher.

Brazil

Forty-six per cent of its primary energy in 2007 was from renewable resources. These consisted of hydropower (15 per cent), sugarcane (16 per cent), wood and charcoal (12 per cent) and other renewables (3 per cent). Further, 80 per cent of Brazil's electricity is generated by hydropower. Besides developing its hydropower potential, Brazil's strategy for clean and renewable energy focuses on ethanol from sugarcane using baggase for power generation, biodiesel from edible oils (mainly soya beans) and the use of wood and charcoal, mainly for industries.

China

China's energy policy has three targets: (i) reduce energy intensity of GDP by 20 per cent over 2006-2010 (ii) increase share of non-hydrocarbon sources to 15 per cent by 2020 and (iii) reduce carbon emission intensity of GDP by 40 to 45 per cent over 2005-2020. Given that more than 90 per cent of energy came from hydrocarbons in 2008, of which coal – much of it high sulphur coal – was 69 per cent, this is a daunting challenge. China has not reached its extremely ambitious first goal. As regards the second objective, in 2008, China's clean energy consumption, including that from hydropower plants, was 282.59 Mtce, which accounted for 9.9 per cent of the total. China has invested heavily in renewable technologies and has become a global leader.

Egypt

To bridge the energy resource gap by 2025 Egypt needs to find 60 tcf of additional gas reserves by 2025, have 25 per cent of its energy from clean alternatives of which 10 per cent should be from nuclear power plants, 5 per cent from solar power plants and other sources and 10 per cent from wind and hydro power plants.

India

India's energy problems arise from meagre oil and gas resources, small wind power potential, limited resources of hydropower and scarcity of land and water. India has a vigorous programme of improving energy efficiency and rapidly developing various renewables such as wind, bio-fuels, mini hydro and solar. The National Solar Mission aims to achieve parity for solar power with coal-based thermal power by the year 2030, and interim grid parity by 2020. India also aims to reduce its emission efficiency by 20 to 25 % by 2020 compared to 2005.

South Africa

South Africa has no oil, little gas and low hydro potential. It is largely dependent on coal with 200 years worth of reserves. In 2008, 71 per cent of energy supply was from coal, 13 per cent from oil, 3 per cent from gas, 2.5 per cent from nuclear and 10 per cent from combustible renewables. It produced 268 mt of coal in 2007 of which 25 per cent was exported and 53 per cent was used for power generation. Despite its plentiful access to wind and solar energy, South Africa has concentrated on fossil fuel development since renewable energy is more expensive to harness. However, given the growing threat of climate change and the growing scarcity of fossil fuels, these resources have to be "embraced", howsoever "reluctantly".

Need for Cleaner and Renewable Energy

CO_2 emissions per unit of energy are lowest for Brazil, way below the global average, reflecting the significant role of hydropower and ethanol in its energy use. China's energy mix is more CO_2 emitting than the global average. The other three countries are around the global average. Also, these countries are responsible for only a small fraction of Green House Gas (GHG) accumulation in the atmosphere. Over 1900-2005 Brazil contributed 1.2% to global emissions, China 14.8%, Egypt 0.5%, India 3.9% and South Africa 1.3%. However, their emissions in future, if left uncontrolled, can be substantial. Thus, there is pressure on them to contain their emissions. For this, the use of renewable energy sources becomes attractive. This will also help these countries reduce their dependence on energy imports.

These countries have promoted programmes consistent with their natural resources. While China, India and South Africa are largely dependent on coal, Brazil uses a lot of hydropower and ethanol from sugarcane. Egypt uses mainly oil and gas but is running out of these. The dependence on imports for oil and energy resources in general is significant for these countries. Brazil launched its ethanol programme in the 1970s when its oil import bill rose dramatically. Egypt has been a net exporter of oil but fears that it will soon need to import oil. Thus, all these countries have their own compulsions to push for the development of renewable and cleaner sources of energy.

Energy Efficiency: The Cleanest Energy

Energy efficiency is the cleanest energy. A "Negawatt" is much more than a "Megawatt". An important way to promote energy efficiency is to have a competitive energy sector where prices of different fuels and forms of energy reflect their opportunity costs. This, however, is not easy since these countries have a large percentage of people who are too poor to be able to afford to pay the full cost of energy. Thus, in South Africa, full marginal cost pricing for electricity connections will imply that the poor will be pushed out of the market.

Energy is a merit good up to a point and subsidising a certain minimum level of consumption is justifiable. Thus, society should bear the cost of connecting poor households to power grids. Similarly, providing clean cooking fuel has many societal benefits and should be subsidised. The important issue here is how to effectively target subsidy to the needy and contain the subsidy bill. The countries have used various measures to promote energy efficiency in specific uses, lighting, appliances, industry, transport and buildings.

Promoting Renewable Energy

Many renewable energy sources today cost more and to promote them, countries have used different policies to provide subsides. For example, Brazil has mandated blending petrol with ethanol and charging consumers the full cost of the blended product. India has used feed-in tariff, renewable portfolio standards and capital subsidies. China has used various fuel incentives, tax concessions, differential pricing and investment subsidies for energy efficient products. We discuss below the issues involved in the development of various renewable and clean energy options.

Hydro Power

Hydroelectric schemes with storage reservoirs provide flexible on-demand power, which can play a very important role in balancing wind and solar power in the grid. Yet storage reservoirs submerge land, often forests, and displace people. Nonetheless, storage of water and transport across space and time are critically important for large countries where water resources are concentrated geographically and temporally. Of course, one should optimise the storage strategy through ground water recharge, small dams, ponds, or large reservoirs. All of them have a role to play. The savings in net GHG emissions for hydropower varies from project to project and may be negative in some cases. Of course, countries still may want to build storage reservoirs for water for cities and for irrigation.

Wind Power

Wind power requires marginal support as feed-in-tariff and can be set up quickly. The main problems are limited availability of wind resources and its low plant load factor.

Thus, in India, the full development of its wind power potential of 100000 MW can supply no more energy than 30000 MW of coal based power plant. Nonetheless, the available potential should be exploited.

Solar Power

These countries have large potential for solar energy and it is a major long-term option. The main difficulty is its high cost. However, costs are coming down and India's solar mission targets it to be coal competitive by 2020. To reach this, however, requires setting a target to reach a certain scale to reap economies of scale, providing subsides in the interim, in ways that encourage competition, cost- reduction and innovation. The reverse bidding process used in India, where suppliers bid for subsidy required in the form of feed-in-tariff for solar power projects, is one way to have market determined level of subsidy. Another way is to stipulate renewable portfolio standards to create a competitive market for different forms of renewables.

Absorbing Renewable Electricity

Wind and solar electricity are not available on demand. While solar power availability is predictable, that of wind power is much less so; hence, large-scale absorption of wind and solar power would require balancing power from hydro plants, pumped storage schemes, gas turbines, etc and a 'smart' grid. The level of 'smartness', however, will depend on particular situations.

Renewable Energy for transport

While electricity will replace some of the liquid fuel required for transport, renewable options need to be developed. Brazil's programme of ethanol, based on sugarcane, and bio diesel, based on soybeans, has been a great success. However, the resources of land and water that Brazil has are not available to others. Second-generation ethanol based on cellulosic material, agricultural wastes and specially grown grasses can be an important option in future; at present, the technology is not economically viable.

To Sum Up

These studies do show that significant potential exists for renewable energy. It will, however, take time and these countries need global environmental space to develop in the meanwhile. Successful development of renewable resources requires targeted policies. These have to be designed carefully to promote cost reduction and innovation.

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Acknowledgement

The paper draws on the five country studies, presented in Dialogue III: Energy, Environment, and Climate Change of the ICRIER-IDRC emerging economies research dialogue, "***Emerging Economies in the New World Order: Promises, Pitfalls, and Priorities***," 12-13 April 2010, New Delhi.

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Kirit S. Parikh*

1. Introduction

The populous, fast growing emerging economies of Brazil, China, Egypt, India and South Africa face daunting challenges on the energy, environment and climate change fronts. Table 1 shows that these five countries accounted for 42 per cent of the global population in 2008, but had only 26 per cent of global energy supply. Brazil, China, Egypt and India have per capita incomes below the global average even in purchasing power parity (PPP) terms; only South Africa has a higher income than the global average. Per capita income grew between 1990 and 2008 at 9.1 per cent in China, 4.7 per cent in India and 2.5 per cent in Egypt. However, in Brazil and South Africa, per capita incomes grew at below the world average.

CO_2 emissions per unit of energy are lowest for Brazil, way below the global average, reflecting the significant role of hydropower and ethanol in its energy use. China's energy mix is more CO_2 emitting than the global average. The other three countries are around the global average.

Table 1: Population, Gross Domestic Product (GDP), Total Primary Energy Supply (TPES) and CO_2 Intensities

Countries	Population in billion (2008)	GDP/cap (2008) in billion PPP 2000 $US	CAGR of per capita GDP in PPP 2000 $ US (1990 to 2008)in %	TPES 2008 (million tonnes of oil equivalent)	percent change of TPES (1990 to 2008)	CO_2 / energy (tonnes CO 2 / terajoule) of 2008	percent change CO_2 /energy from 90 to 2008
Brazil	0.19	8582	1.6	249	77	35	5.9
China	1.33	8295	9.1	2131	144	73	19.4
Egypt	0.08	4243	2.5	71	122	59	-1.1
India	1.14	3781	4.7	621	95	55	24.1
South Africa	0.05	10920	1.0	135	48	60	-10.5
total 5 countries	**3**			**3205**			
World	6.69	9549	2.3	12267	40	57	0.3
5countries/ world	**0.42**			**0.26**			

Source: http://www.iea.org/co2highlights/co2highlights.pdf (International Energy Agency)

* Chairman, Integrated Research and Action for Development (IRADe) and Former Member, Planning Commission, Government of India.

Energy consumption in these countries is growing. With economic growth and higher populations, the demand for energy would be even higher. At the same time, while they are responsible for only a small fraction of Green House Gas (GHG) accumulation in the atmosphere (see table 2), their emissions in future, if left uncontrolled, can be substantial. Thus, there is pressure on them to contain their emissions. For this, the use of renewable energy sources becomes attractive. This will also help these countries reduce their dependence on energy imports.

Table 2: CO_2 Emissions, Total, Per Capita and Cumulative from 1900-2005

Countries	CO_2 eq. for 2007		CAGR (2000 to 2007) in %		Cumulative Emissions (1900 - 2005)	
	Total	*Per capita (metric tonnes)*	*Total*	*Per Capita*	*Total (Mt CO_2e)*	*% World*
Brazil	374	2.0	1.7	0.6	4572	1.2
China	6703	5.1	9.1	8.8	55150	14.8
Egypt	189	2.4	5.5	3.7	1847	0.5
India	1410	1.3	4.0	3.3	14633	3.9
South Africa	353	7.4	1.9	0.9	4666	1.3
5 Countries	**9029**	**18.2**			**80869**	**22**
World	**29630**				**373312**	

Source: http://cait.wri.org/cait.php?page=yearly (World Resource Institute)

Table 2 shows the CO_2 emissions in 2008 and the cumulative emissions over the period between 1990 and 2005. The per capita emissions of Brazil, Egypt and India are less then half that of China and less than one-third that of South Africa and are way below the global average. The emissions of China and South Africa exceed global average. These countries grow at different rates and have different resources. Their problems differ and so do their approaches to the development of renewable sources of energy.

2. Energy mix

Table 3 provides the source wise energy supply in these countries.

Table 3: Total Primary Energy Supply and Percentage Share of Sources for 2008

TPES (%)	Brazil	China	Egypt	India	South Africa
Coal and Peat	5.5	66.4	1.2	42.1	71.3
Crude oil & Oil prod.	38.5	17.2	45.8	23.3	12.8
Gas	8.5	3.2	49.1	5.7	3.1
Nuclear	1.5	0.8	0.0	0.6	2.5
Hydro	12.8	2.4	1.8	1.6	0.1
Geothermal, Solar, etc	0.1	0.3	0.1	0.2	0.0
Combustible renewable	31.6	9.6	2.1	26.3	10.4
Electricity Imports	1.5	-0.1	-0.1	0.1	-0.2
Heat	0.0	0.0	0.0	0.0	0.0
Total Supply* (ktoe)	248528	2116427	70710	620973	134489
Total net imports (ktoe)	20920	174462	-16929	153001	-21046
Stock Changes(ktoe)	-518	-51341	151	-336	-7415
Total domestic production (ktoe)	**228126**	**1993306**	**87488**	**468308**	**162950**

*Totals may not add up due to rounding

Source: http://www.iea.org/stats/index.asp (International Energy Agency)

While China, India and South Africa are largely dependent on coal, Brazil uses a lot of hydropower and ethanol from sugarcane. Egypt uses mainly oil and gas but is running out of these. Table 4 shows net imports of different fuels and forms of energy.

Table 4: Net Imports in 2008 as Percentage of Supply

Net Import**/ TPES (%)	Brazil	China	Egypt	India	South Africa
Coal and Peat	86.0	-1.1	98.2	14.0	-40.9
Crude oil & Oil Prod.	-1.3	52.2	-9.9	73.5	94.5
Gas	44.6	1.7	-41.6	26.1	58.2
Nuclear	0.0	0.0	0.0	0.0	0.0
Hydro	0.0	0.0	0.0	0.0	0.0
Geothermal, Solar, etc	0.0	0.0	0.0	0.0	0.0
Combustible renewable	-3.4	0.0	-1.4	0.0	-1.9
Electricity	1.5	-0.1	-0.1	0.1	-0.2
Total Net Imports/ TPES*	8.4	8.2	-23.9	24.6	-15.6

*Totals may not add up due to rounding.

** net imports includes marine and air bunkers

Source : Based on http://www.iea.org/stats/balances.asp

The dependence on imports for oil and energy resources in general is significant for these countries. Brazil launched its ethanol programme in the 1970s when its oil import bill rose dramatically. Egypt has been a net exporter of oil but fears that it will soon need to import oil. Thus, all these countries have their own compulsions to push for the development of renewable and cleaner sources of energy.

3. Approaches followed to develop renewable energy

The authors of the five country case studies (Moreira, Gao, Selim, Sawney & Mehra and Fig) have followed different approaches to deal with their perceived problems in the context of their own resources. There are differences and similarities in their approaches. We first look at the five countries in turn.

3.1. Brazil

The main points that emerge from Jose Moreira's (2011) paper, "Brazilian Perspective on Clean Energy" are summarised below. Brazil has vast land and water resources. Its strategy for clean and renewable energy, therefore, is based on this advantage. Forty-six per cent of its primary energy in 2007 was from renewable resources. These consisted of hydropower (15 per cent), sugarcane (16 per cent), wood and charcoal (12 per cent) and other renewables (3 per cent). Further, 80 per cent of Brazil's electricity is generated by hydropower. Besides developing its hydropower potential, Brazil's strategy for clean and renewable energy focuses on ethanol from sugarcane using baggase for power generation, biodiesel from edible oils (mainly soya beans) and the use of wood and charcoal, mainly for industries. Half of the wood comes from special wood plantations. Improved energy efficiency, of course, is a major option. To the extent that quantity of wood extracted from natural forests exceeds natural growth and leads to deforestation, it cannot be considered renewable energy.

Ethanol

The ethanol programme, based on sugarcane, started in 1975 and has seen dramatic growth. The growth rate of ethanol production has fluctuated a lot. It was 37 per cent a year during 1976-1986, 1.6 per cent a year from 1986-1999, -4.2 per cent a year between 1999 and 2003, but 13.5 per cent a year from 2003 to 2008. These fluctuations resulted from government policies, international oil prices and international sugar prices. Brazil promoted ethanol by subsidising producers and mandating blending. Ethanol price was capped at 59 per cent of gasoline price during 1980-85 and service stations were required to have one dedicated ethanol pump. That encouraged neat ethanol cars introduced in the market in 1980. Today, most cars in Brazil are flexi-fuel cars. Ethanol has over the years replaced gasoline and its production surpassed gasoline consumption in 2009. The subsidy on ethanol is recovered by charging a higher price for gasoline so that the burden is on gasoline consumers.

Moreira argues that the ethanol programme has resulted in a net gain to consumers who have saved billions of dollars over the years as competition from ethanol led to lower gasoline prices when price was freed from government control. The ethanol programme has also helped improve the country's balance of payments and reduced the debt burden. Sugarcane plantations covered 7.8 Mha (million hectares) in 2008 and are expected to cover 14Mha by 2039. The cumulative GHG saving from ethanol is estimated to be 820 tonnes of CO_2 per hectare over 35 years.

Biodiesel

Brazil launched its biodiesel programme in 2005 based on soya oil. Since vegetable oil crops were already available, the growth in biodiesel has been a phenomenal 13.5 per cent a month from January 2006 to March 2009. Soya bean production reached nearly 60 Mt in 2006-07. At present, there is compulsory blending of 2 per cent, which will be raised to 5 per cent by 2013. Biodiesel demand reached 2.24 million m^3 in 2010. The net gain in terms of GHG emissions from biodiesel based on soya beans is not clear. When the land use change (LUC) and induced land use change (ILUC) are accounted for, at least for the USA, it was found that biodiesel emissions would be 4 per cent higher than from the use of diesel oil. For Brazil's sugarcane-based ethanol programme, GHG emissions including LUC and ILUC would be less than that from the gasoline replaced.

Charcoal:

Brazil used some 9.5 Mt (million tonnes) of charcoal in 2008, of which industry accounted for some 7.5 Mt, households for around one Mt and other energy use around one Mt. Charcoal in Brazil is not a fully renewable product as nearly half of it was produced from native vegetation in 2004.

Hydro Energy

In 2008, Brazil generated around 470 GWhr of electricity, imported 45 GWhr from the Itaipu plant owned by Paraguay and consumed around 430 Gwhr, after accounting for losses. Hydro electricity provided 79 per cent of total electricity supply. In 2009, the installed capacity of hydro plants was 81,669 MW out of a total installed generating capacity of 107188 MW. With 11,780 MW under construction, some 41,100 MW of hydro capacity addition is expected by 2017. Despite this, the share of hydro will come down to 70 per cent. The environmental and social barriers are limiting the growth of hydro capacity as in India. This has led to an interest in small hydro projects that have smaller environmental and social problems but also have much lower potential. The installed capacity of small hydro projects is expected to reach 7700 MW by 2017.

Wind energy

Wind energy potential in Brazil has been assessed at 73,000 MW. The present installed capacity is around 1 MW and is not projected to be substantial. What is interesting is that changes in bidding conditions that provided easier access to transmission and distribution networks have led to substantially increased interest in bidding for wind power.

Energy Efficiency

Energy efficiency is often considered the largest and cleanest energy source. Energy efficiency programmes have registered modest gains in Brazil. In 2008, it is estimated to have saved 4.4 GWhr of electricity and 1569 MW of installed capacity. The benefit cost ratio has been estimated at 20:1. The main problems that impede an improvement in efficiency are the lack of commercial bank credit and inadequate numbers of energy service companies (ESCOs).

3.2. China

As Shixian Gao (2011) describes in his paper "Energy, Environment and Climate Change", China's energy policy has three targets: (i) reduce energy intensity of GDP by 20 per cent over 2006-2010 (ii) increase share of non-hydrocarbon sources to 15 per cent by 2020 and (iii) reduce carbon emission intensity of GDP by 40 to 45 per cent over 2005-2020. Given that more than 90 per cent of energy came from hydrocarbons in 2008, of which coal – much of it high sulphur coal – was 69 per cent, this is a daunting challenge. China has not reached its first goal, which was extremely ambitious to begin with. As regards the second objective, in 2008, China's clean energy consumption, including that from hydropower plants, was 282.59 Mtce, which accounted for 9.9 per cent of the total. This is given in Table 5.

Table 5: Clean Energy Production in China in 2008

	Capacity	Unit	Production	Unit	Mtce
Power Generation	195940	MW	654.22	Gwh	244.29
Hydro	171520	MW	563.3	Gwh	210.74
Nuclear	9100	MW	68.4	Gwh	25.59
Wind	12170	MW	14.8	Gwh	5.33
PV	150	MW	0.22	Gwh	0.08
Biomass	3000	MW	7.5	Gwh	2.55
Biogas			14	Gwh	10
Household use	30	Million unit			
Large Projects	1600	Unit			
Heating					28.3
Solar water heaters	125	Million m sq			25
Solar cookers	0.45	Million unit			0.1
Geothermal	40	Million m cube	80	TJ	3.2
Bio fuels	1.65	Mt			1.55
Total					282.59

Source: Gao S. (2011)

Hydropower

The hydro capacity has been steadily increasing from 52 GW in 1995 and by 2008, China had 171.52 GW of hydropower capacity accounting for 21.6 per cent of the national total. It generated 563 billion kWhr (b kWhr) of electricity from hydro plants.

Nuclear power

The installed nuclear power capacity was 9.1 GW in 2008 and generation was 68.4 billion KWhr. In 1995, they were 2 GW and 13 bkWhr respectively.

Wind power

China's wind power capacity grew at 56.1 per cent per year from 344 MW in 2000 to 12170 MW in 2008.

Solar

China has built up capacity to manufacture 2 GW of Photo Voltaic (PV) cells a year; however, much of the PV cells are exported and its domestic installed capacity was only 150 MW in 2009. Solar water heaters are widely used in China and 125 million m^2 of collectors are installed. Its manufacturing capacity is 25 million m^2 per year.

Biomass

Thirty million biogas units produce 13 billion m^3 of biogas for 80 million rural persons for household use. Biogas for industrial use is just beginning and, in 2008, biogas production was only 1.55 Mtce. To reach its third target by 2020, the installed capacity of hydropower, wind power, nuclear power and biomass power are expected to be 340 GW, 120 GW, 70-80 GW and 40 GW respectively.

Energy efficiency

The elasticity of energy consumption with respect to GDP in China over 2006-2008 was 0.65. In most energy intensive products, specific energy per unit of output decreased over 2005 to 2007. The highest reductions were in plate glass (22.73 per cent), steel smelters (21.79 per cent) and coal production (10.11 per cent).

For promoting energy efficiency, China provides various fiscal incentives, tax concessions, differential pricing, investment subsidies for energy efficient products etc. It plans to concentrate on high energy-intensive sectors and promote the substitution of less energy efficient equipment and fuels with more efficient ones, waste heat recovery, combined heat and power, efficient lighting, efficient buildings, technical service organizations and government institutions for saving energy.

3.3. Egypt

Tarek Selim (2011) in his paper "Towards a New Energy and Environment Policy for Egypt: Development of Clean Sources in an Emerging Economy" describes Egypt's concerns and approach. Egypt's energy problem is different from that of other emerging economies. It has been an oil exporter with oil exports providing 40 per cent of its export earnings. Oil production has been decreasing over the past decade. Egypt became a net importer of oil in 2008. In 2025, oil imports may reach 57000 barrels a day (about 29 million tonnes per year). Fortunately, large gas reserves have been found and gas production has doubled between 1999 and 2003. In 2005, it was 1000 times more than in 1985.

The Egyptian economy has shifted from oil to gas and Egypt ranked third in the world in natural gas consumption with a daily consumption of 2.6 billion cubic feet (bcf). Of the total electricity generated in Egypt, 88 per cent is based on natural gas while the remaining 12 per cent is hydro electricity from the Aswan high dam. The total installed capacity in 2008 was 23 GWe. Selim argues that Egypt should find 60 tcf of additional gas reserves by 2025, increase gas production and have a gas export target of 18 bcf/d by 2025. Egypt does not have a single commercial nuclear power plant. However, Selim suggests that Egypt should commission 4GWe by 2030 and 7GWe by 2050 of nuclear power based on light water reactors (LWRs). Despite being the home of the Sun god Ra and despite a history of Pharaohs using solar energy for heating thousands of years ago, solar energy is used very little is Egypt. Subsidised oil and gas make solar water heaters even less attractive.

According to Selim, to reach energy sustainability and bridge the energy resource gap by 2025, Egypt needs to have 25 per cent of its energy from clean alternatives of which 10 per cent should be from nuclear power plants, 5 per cent from solar power plants and other sources and 10 per cent from wind and hydro power plants.

3.4. India

Aparna Sawhney and Meeta Mehra (2011) offer an Indian perspective on clean energy and energy efficiency. They have used projections by the IEA (2008), which are based on a low growth rate of GDP of 6.3 per cent over 2005-30. The IEA projection of TPES for 2030 is 1299 Mtoe. Compared to this, the expert committee report on integrated energy policy, Planning Commission (ECOIEP, 2006), has projected for 2031-32, 1536 to 1887 mtoe for a growth rates of 8 per cent. India's growth rate over 2005 to 2010 has exceeded 8 per cent despite the global meltdown of 2008. The 12^{th} plan's growth rate target is 9 per cent to 10 per cent. India can attain these growth rates and sustain them over some decades just as China, for example, had a growth rate of around 9.5 per cent over 1980 to 2005. The projections by IEA and by the ECOIEP are summarised in Table 6. The projected demands for energy by IEA used by Sawhney and Mehra are too low and do not reflect the Indian perspective.

Nevertheless, the discussion on energy efficiency and clean energy options is not affected by the very low projections of energy needs by IEA.

Table 6: India's Energy Need Projections by IEA and ECOIEP

Item	IEA 2030	ECOIEP 2031-32*
Total primary energy demand (MTOE)	1299	1536 - 1887
Coal	620	632-1032
Oil	328	350-486
Gas	93	104-197
Nuclear	33	76-98
Hydro	22	13-35
Biomass and waste	194	185
Other renewables	9	2

** Expert Committee on Integrated Energy Policy, Panning Commission (2006), Assuming 8% growth rate of GDP*

India’s energy problems arise from meagre oil and gas resources, small wind power potential, limited resources of hydropower and scarcity of land and water coupled with a fast growing economy and a large and increasing population. India’s clean energy options in the medium term are improving energy efficiency and rapidly developing renewables that are economical today.

Renewables

The Indian government has initiated a number of policy measures to promote renewable energy.

a. Capacity/ Generation Targets for Specific Renewable Forms:

Solar energy is used to produce electricity through either photovoltaic or concentrated solar power, and is also used to supply heat to the residential sector and industrial processes – solar heating and cooling. Since India has abundant solar resources, equivalent to over 5,000 trillion kWh annually, there are now concerted efforts to promote the harvesting of this form of energy to meet India’s escalating energy demand.

- The 11th 5-year plan has aimed at grid-connected solar power generation. The current capacity in solar power is about 50MW, which is intended to be increased to 20GW by 2020.
- The National Solar Mission aims to achieve parity for solar power with coal-based thermal power by the year 2030, and interim grid parity by 2020. The aim is to make solar power commercially viable over the next two decades, such that solar power and generator investors would no longer face technical or financial constraints. The capacity goal for 2030 is set at 100 GW, constituting 10-12 per

cent of total power generation (and an interim capacity goal of 20GW by 2020, PMO 2009).

- Under the National Solar Mission, the government will support the setting up of dedicated manufacturing capacity of poly silicon material as well as solar thermal collectors and receivers. Special Economic Zone-type of incentives will be offered for the establishment of solar technology manufacturing parks.

There are also plans to establish 60 "solar cities" that would reduce energy demand by 10 per cent with increased renewables and efficiency by 2012. Nagpur and Rajkot have been identified as two of the first cities under this programme.

Fiscal Incentives for Renewable Energy Investment:

- The national and state governments have offered capital investment subsidies of 20 per cent to support solar PV manufacturing in special economic zones.
- Generation-Based Incentives (GBI) have been proposed at Rs10/Kwh for the first three years with reviews in subsequent years under the National Solar Mission. The GBI would be valid for 20 years (from date of project commissioning/generation) to ease the burden on utilities from fixed tariffs for solar power. The GBI will be paid by the central government through state designated agencies in different states.
- Specific capital equipment and project imports will be exempt from customs and excise duties for solar power. Concessional loans will be given (10-year loans at 2 per cent interest rate) to off-grid solar PV of 100W to 10kW to displace diesel generators, UPS and for invertors with solar base.

- For wind power projects, incentives include fiscal concessions such as 80 per cent accelerated depreciation, concessional custom duty for specific critical components, excise duty exemption, income tax exemption on profits from power generation, etc. (MNRE 2009).

Demonstration Projects:

- The MNRE started a new demonstration programme, permitting utilities, generation companies and state nodal agencies to set up grid-connected, solar photovoltaic plants of 25 kWp (kilo watt peak) to 1,000 kWp capacity. For this, the scheme provides support of 50 per cent of the basic cost of the plant, subject to a maximum of Rs.10 crore per MWp (available to set up 4 MWp aggregate capacity projects in the country during the 11th plan period).

Preferential Tariffs and Fiscal Incentives for Generation

- The National Solar Mission would require mandatory solar power purchase under RPO (renewable portfolio obligation), may be with 0.25 per cent in Phase I and increasing to 3 per cent in Phase III.
- State Electricity Regulatory Commissions in several states offer preferential tariff for purchase of power from wind power projects.
- A generation-based incentive was initiated in 2007-08 by the Ministry of New and Renewable Energy to attract a large number of independent wind power producers (limited to a capacity of 49 MW) who do not avail the benefit of accelerated depreciation. The investors, apart from getting the tariff as determined by the respective state regulatory commissions, would get an incentive of 50 paisa per unit of electricity for a period of 10 years if they do not claim the benefit of accelerated depreciation. (MNRE 2009).

The fiscal concessions and tax benefits seem to have succeeded in enhancing the installed capacity of wind power in the country, with over 10 GW installed capacity in 2009. The policies and achievement-specific renewable options are as follows:

Wind power

Wind power is the fastest growing renewable energy source and reached an installed capacity of 14,158 MW as of March 31, 2011. This has been achieved through capital subsidies in the form of enhanced depreciation allowance. This is being changed now into a feed-in tariff mechanism to give incentives to generate wind power as opposed to merely installing generating capacity.

The total potential for wind power is estimated to be 48,561 MW by MNRE and 65,000 MW by the Wind Power Society of India. In any case, since the plant load factor of installed wind power capacity is less than 20 per cent on an average, even 65000 MW would provide no more energy in terms of kWhr of electricity per year than 20000 MW of coal power plant operating at 70 to 80 per cent plant load factor.

Solar Energy

India views this as a major long-term energy source, renewable or otherwise. As a result, the national action plan for climate change (NAPCC, 2008), has identified a national solar mission to develop solar energy in India. The mission's primary aim is to make solar electricity cost competitive to coal-based electricity by 2030 and, in the interim, attain grid parity by 2020. To achieve this, 20,000 MW of solar capacity is to be created by 2020 and 100,000 MW by 2030 through incentives. This will help achieve cost reduction through economies of scale and also through competition as subsidies in the form of feed-in tariff will be given through a competitive bidding process. Firms are required to bid for the feed-in tariff they need and the first auction has already lowered the feed-in tariff to Rs 13/kWhr from a ceiling of Rs 15. As of 2010, already 700 MW have been allotted.

Further, to promote renewable energy, many state electricity regulatory commissions (SERCs) have announced a renewable portfolio obligation and the certificates can be traded, for which power exchanges provide electronic trading platforms.

Apart from solar electricity, solar water heaters are also promoted through a capital subsidy. As of 2010, some 3 million sq. m of collectors have been installed. A capital subsidy, however, provides little incentive to reduce costs. Chinese water heaters were displayed at the Delhi International Renewable Energy Conference (DIREC) at one-fourth the price of Indian ones.

Other Renewables

Under the Remote Village Electrification Programme in India, 4,250 villages and 1,160 hamlets had been electrified using renewables by 2009. India's Integrated Rural Energy Programme, using renewable energy, had served over 300 districts and 2,200 villages by 2006, with additional projects under implementation in over 800 villages and 700 hamlets in 13 states and union territories (REN21 2009). This is to be viewed in the context of an estimated 25000 villages categorised as remote villages. Villages do not want to be classified as a remote village as they all want grid power.

Solar PV applications have increased to more than 435,000 home lighting systems, 700,000 solar lanterns, and 7,000 solar-powered water pumps. India has more than an estimated 240 million households, 70 per cent of which are in rural areas.

India has had a bio gas programme since the early 1960s (see Parikh K. S., 1963). While millions of family-sized plants have been installed, evaluation studies show that only half of them are in use. In any case, if all of the around 15 million families, who have enough cattle to run a family-sized biogas plant, install a plant and if all these function, they would provide around 6 Mtoe of energy per year at most.

Energy efficiency

India's energy intensity in terms of Kgoe/$ GDP is better than most countries (see Table 7). Yet, there is scope for further improvement.

Table 7: Energy intensity in 2007 (kgoe/1990 US$ value added)

Country or area	Total	Agriculture	Industry	Transport	Commercial & others	Total (kgoe/ capita)
Australia	0.15	0.14	0.20	0.44	0.02	3641
Brazil	0.25	0.10	0.30	1.40	0.03	998
China, People's Republic of	0.58	0.21	0.48	1.26	0.07	956
Germany	0.11	0.11	0.08	0.33	0.02	2831
India	0.45	0.11	0.47	0.37	0.03	337
Indonesia	0.53	0.07	0.42	0.93	0.04	646
Japan	0.09	0.05	0.07	0.30	0.03	2682
Saudi Arabia	0.47	0.03	0.15	2.46	0.05	3756
United Kingdom	0.10	0.05	0.09	0.29	0.02	2345
United States	0.17	0.08	0.13	0.83	0.03	5144

Source: IEA, 2009 and United Nations Statistical Division (UNSD) Energy intensity in agriculture may increase in future due to greater mechanization. On the other hand, as some 7 million diesel pumps get electrified, energy intensity may come down.

A Bureau of Energy Efficiency (BEE) has been set up to promote energy efficiency. It has launched a number of programmes.

(a) A"Bachat Lamp Yojana" (BLY), literally a "saving lamp scheme" has been launched, under which incandescent lamps (ILs) are replaced free of cost by compact florescent lamps (CFLs), the cost of which is recovered from carbon credits.

(b) Energy-using appliances are labelled and given a star rating, which indicates energy efficiency and savings in electricity consumption. This encourages consumers to buy more energy efficient products.

(c) Buildings consume a lot of energy. Energy efficiency in buildings is quite important. By appropriate design, using natural sunlight and appropriate orientation, insulation and natural sources of cooling and heating, one can save a substantial amount of energy. This is in excess of energy that can be saved by more efficient equipment such as air conditioners. An Energy Conservation Building Code (ECBC) has been formulated. Buildings built according to the code are expected to save at least 30 per cent of the energy used in the buildings. The code is made mandatory for large buildings in a few places and coverage is expected to be expanded over time.

(d) A Perform, Achieve and Trade (PAT) scheme for industries has been launched to promote energy-use efficiency in industries (BEE 2011). Under this scheme, designated firms (some 700 of them) are set mandatory energy efficiency standards. The firms trade their excess or deficit of energy consumption allowance. The scheme has the advantage of a market mechanism that leads to achieving efficiency targets at least cost. However, there is no economic cost minimisation in the way firm-specific standards are set. The penalty for not meeting targets is specified as the cost of a tonne of oil equivalent not saved. The trading will begin in 2012 and experience will show how the system functions and suggest ways to refine it.

The interim report of the Expert Group for "Low Carbon Strategy for Inclusive Growth" (EGOLCSIG, 2011) has estimated a reduction in emission intensity (kgoe/$ GDP) of 24 per cent by 2020 over 2005 through determined effort and 34 per cent through aggressive effort.

3.5. South Africa

David Fig's (2011) paper, "Reluctant Embrace: South Africa and Renewable Energy" discusses the adoption of renewable energy sources in South Africa. South Africa has no oil, little gas and low hydro potential. It is largely dependent on coal with 200 years worth of reserves. In 2008, 71 per cent of energy supply was from coal, 13 per cent from oil, 3 per cent from gas, 2.5 per cent from nuclear and 10 per cent from combustible renewables. It produced 268 Mt of coal in 2007 of which 25 per cent was exported and 53 per cent was used for power generation.

Installed capacity for electricity generation was 39,154 MW in 2007 of which coal-based capacity was 34,882 MW, nuclear 1930 MW and hydro including pumped storage just 670 MW. Electricity supply is by a state-owned, monopoly utility, ESKOM , which was commercialised in early 2005 though it remains a public enterprise. It is under financial stress and reported a loss of R 9.7 billion in FY 2009. A regulator controls the price of electricity. Many poor, not provided electricity earlier, are now required to pay marginal connection charges and are not able to afford electricity and disconnections are not infrequent. ESKOM's financial rating has gone down and it is unable to raise resources to expand capacity. Despite power shortage, South Africa supplies cheap electricity to aluminium smelters, in effect, exporting cheap electricity and suffering local air pollution.

South Africa's nuclear programme is old. Since 1990, it has been developing a Pebble Bed Modular Reactor (PBMR). However, the earliest commercial plant is due only around 2025.

Renewable Sources of Energy

Despite its plentiful access to wind and solar energy, South Africa has concentrated on fossil fuel development like many other countries. Since renewable energy is more expensive to harness, this is understandable. However, given the growing threat of climate change and the growing scarcity of fossil fuels, these resources have to be "embraced", howsoever "reluctantly".

South Africa's wind power potential is estimated to be 1000 MW by ESKOM and 50000 MW by Schaeffer (2005). Solar potential is estimated to be 58000 MW (see Salgado, 2009). South Africa's hydro potential is very small, given that its rivers are unreliable. South Africa has announced a target of 10000 GWhr, about 4 per cent of current energy generated, of renewable energy by 2013. It is nowhere near meeting this target. The development of renewable energy suffers from fragmentation of responsibility for the energy sector among different ministries – a situation similar to that in India, where eight ministries look after the energy sector.

South Africa had announced in December 2009 on the eve of the Copenhagen Conference that it would reduce its emissions by 34 per cent by 2020 and 42 per cent by 2025 below the business-as-usual projections, subject to the availability of finance and access to technology. South Africa has stipulated feed-in tariffs for different renewable energy sources ranging from R 0.94 per kWhr for small hydro to R 3.94 for grid-connected solar PV exceeding 1 MW. However, investors have complained that there is no corresponding purchase promise from ESKOM. This creates uncertainties.

Among the few small projects in renewable energy are a CDM project to provide solar water heaters and CFL lamps to 2309 households in an urban settlement on the outskirts of Cape Town, a rural wind farm project to generate 40 MW of electricity by 2013 in Tsitsikame in the Eastern Cape province, an on-again, off-again 100 MW solar power plant to be set up by ESKOM and a 10 GWhr wind power project at Darling, the first phase of which was completed in 2008. One can see that progress in renewables in South Africa is miniscule.

4. Insights from the case studies

Comparison of these case studies provides some insights.

Importance of Resource base

Energy policies, issues and strategies of these countries are dominated by their resource base. Thus, Brazil with its abundance of land and water has promoted hydropower and sugar cane-based ethanol. This is not an option that China, Egypt, India or South Africa can follow. Egypt, on the other hand, had surplus oil and now has natural gas. It has seen no compulsion until now to promote renewable energy – not even solar energy. Egypt is more concerned about how to make a transition from being an oil exporter to being an oil importer. The transition has been made difficult because, like many other oil rich countries, it has kept consumer prices for petroleum products at low levels. For China, India and South Africa, coal is the most abundant resource; they are poorly endowed with oil and gas resources. Their energy economies are centred on coal. China and India recognise the need to shift away from coal and have strong programmes to promote energy efficiency and clean and renewable sources of energy. South Africa, on the other hand, is only "reluctantly embracing" renewables.

Energy Security - A Major Driver

All these countries are driven by their desire to reduce their dependence on imported energy. Energy from domestic renewable energy sources is thus very attractive. Even more attractive is promoting energy efficiency that reduces the need for energy in the first place. The promise of abundant energy from nuclear power is also a factor in pursuing nuclear energy or at least keeping the nuclear option open.

Energy Efficiency -The Cleanest Energy

Energy efficiency is the cleanest energy. A "Negawatt" is much more than a "Megawatt". An important way to promote energy efficiency is to have a competitive energy sector where prices of different fuels and forms of energy reflect their opportunity costs. This, however, is not easy since these countries have a large percentage of people who are too poor to be able to afford to pay the full cost of energy. Thus, in South Africa, full marginal cost pricing for electricity connections will imply that the poor will be pushed out of the market.

Energy is a merit good up to a point and subsidising a certain minimum level of consumption is justifiable. Thus, society should bear the cost of connecting poor households to power grids. Similarly, providing clean cooking fuel has many societal benefits and should be subsidised. The important issue here is how to effectively target subsidy to the needy and contain the subsidy bill. The development of information and communication technology (ICT) provides an opportunity to do so. (Parikh K.S, 2011, TOI article). Countries have used various measures to promote energy efficiency in specific uses. Some problems in these measures and policies are described below.

Lighting

How does one promote the use of more efficient CFL or LED lights in countries where many of the consumers are poor for whom the first cost is very important and future savings are of relatively lesser value?.

Two approaches are generally used. The first is one where the distribution utility loans the more efficient CFL and adds a monthly charge to the customer's bill. The customer does not feel any financial burden if the monthly charge is less than the value of electricity saved. Such a system does not work well if domestic consumers are charged a flat fee or are supplied electricity at subsidised price. The relatively well off might have no financial constraint in "switching over" to more efficient lights. On the other hand, for them the cost of electricity for lighting may constitute a small fraction of their expenditure and they may not bother to change. Some of them have sophisticated lighting for a room with indirect light from many lamps.

India has used a different mechanism. In its "Bachat Lamp Yojana" (literally saving lamp scheme), a working incandescent bulb is exchanged free of cost with a CFL by the distribution company, which has worked out a scheme to get carbon credits for its programme. Chips are introduced in a small number of randomly selected CFLs that measure the number of hours the bulb is turned on. This provides a verifiable estimate of carbon emissions saved.

Energy Efficient Appliances

Energy efficient appliances are often promoted through an appliance-rating scheme in many countries. The appliances are rated with one to five stars, five stars referring to the most energy efficient model. The label carries the amount of electricity consumed by the appliance and its energy efficiency. A buyer can thus decide if the savings are worth the additional cost of an appliance with more stars. Thus, for example, 1.5 ton air conditioners (AC) with different characteristics are rated as shown in *Table 8*.

Table 8: Rating and Characteristics of a 1.5 ton Air-conditioner (used 4 hours a day)

Star ranking	Energy Efficiency Ratio (Min)	cooling capacity (max)	Input power	Units consumption per day	per unit charge (approx.)	Electricity cost/month	cost saving per year (w.r.t. no star) approx
		Watts	*Watts*	*kWh*	*Rs.*	*Rs.*	*Rs.*
No star	2.2	5200	2364	9.45	2.5	709	0
1	2.3	5200	2261	9.04	2.5	678	308
2	2.5	5200	2080	8.32	2.5	624	851
3	2.7	5200	1926	7.7	2.5	578	1313
4	2.9	5200	1793	7.17	2.5	538	1712
5	3.1	5200	1677	6.71	2.5	503	2059

Source: BEE website http://www.bee-india.nic.in/schemes/documents/ecbc/eco3/SnL/Guide%20on%20EnergyEfficient%20Room%20Air%20Conditioner.pdf

Often, a 5-star AC comes with additional features. This makes it difficult to assess the impact of the labelling programme. Did a consumer buy it for the additional features or for the saving in electricity? While private individuals and firms would make an economically rational choice, it is not easy for procurement officers of public sectors firms or government departments to do so. They are required to buy on the lowest first-cost basis. They need to be empowered to buy on the basis of life-cycle cost. This can be done by estimating the present discounted value of savings in electricity cost over the lifetime of the equipment.

Table 9: Present Discounted Value in Rupees of Saving over No Star Model over 5 years at Discount rates of 10 % and 15 %

Star rating	10 %	15 %
1	1168	1032
2	3226	2853
3	4977	4401
4	6490	5739
5	7805	6902

Source: Parikh Kirit S. (2011a)

Table 9 gives the premium that may be paid over a no-star rated model for different star-rated models with a 5-year life and an electricity price of Rs. 2.5/kWhr. Thus, it would be worthwhile to buy a 5-star AC if the price difference as compared to a no-star rated model is Rs 7800 with a discount rate of 10 per cent and Rs 6900 with a discount rate of 15 per cent. The procurement officers should be so empowered. Such a scheme will still be consistent with competitive bidding and firms will have to match the performance of the no-star produce with the higher star-rated products of other firms. Since the public sector is a major purchaser of such equipment, such a measure would be very useful in promoting energy efficiency.

Promoting Energy Efficiency in Industry:

Since industries are growing rapidly in these countries, the industrial capital stock will double every seven to eight years. Thus, concentrating on new industries to set up energy efficient plants is an attractive option. Labelling for industrial equipment, such as variable speed drives, can be effective if energy prices are competitively determined.

This is where countries have yet to move. For example, in India, the government has accepted the Integrated Energy Policy Planning Commission (2006) report. The principal recommendations of having a competitive energy sector by pricing various fuels at their opportunity cost, i.e., at trade parity prices, has not yet been implemented, Diesel and natural gas prices are set by the government and are priced below what would have been their prices in competitive markets. Coal price is also not market-determined and is below its trade parity price. Due to these distortions, labelling for industrial equipment would not realise its full potential.

Further, in these countries, many small and medium enterprises (SMEs) also contribute substantially to industrial production. The Indian PAT scheme covers only some 700 large firms. The main challenge is posed by the millions of SMEs. They are not covered by the PAT scheme. Some of these SMEs are located in clusters. The BEE is examining some 25 clusters to see how these SMEs can be incentivised to improve energy efficiency. The results would be of interest to all the other countries.

Energy Conservation in Buildings

BEE in India enacted an energy conservation building code (ECBC), BEE (2009), which has been mandatory for large commercial buildings. Since the services sector is the largest sector in the Indian economy and is also growing faster than other sectors, this is a very important measure. New office buildings, many air-conditioned, are being built at a rapid pace. This is true in other countries as well. The effective implementation of codes such as the ECBC implies that architects need to be trained to design buildings appropriately. It is also necessary to enforce the code. Code enforcement falls under the jurisdiction of sub-national states and local municipal authorities. This poses hurdles that need to be overcome.

What the Indian code considers is energy used per square metre of built up area. However, this is not always an appropriate measure. For example, the new air terminal in New Delhi is considered a very energy efficient building. Yet it requires 220 MW of electricity as compared to about 25 MW by the old terminal catering to a similar number of passengers. An appropriate measure of energy efficiency would be KWhr per passenger handled.

5. Promoting clean and renewable energy

Many renewable energy sources today cost more and to promote them, countries have used different policies to provide subsides. For example, Brazil has mandated blending petrol with ethanol and charging consumers the full cost of the blended product. India has used feed-in tariff, renewable portfolio standards and capital subsidies. China has used various fuel incentives, tax concessions, differential pricing and investment subsidies for energy efficient products. We discuss below the issues involved in the development of various renewable and clean energy options.

Hydro Power

Hydroelectric schemes with storage reservoirs provide flexible on-demand power, which can play a very important role in balancing wind and solar power in the grid. Yet storage reservoirs submerge land, often forests, and displace people. Thus, many people oppose the construction of dams, particularly large ones on environmental and social grounds. Nonetheless, storage of water is critically important for large countries where water resources are concentrated geographically and temporally. Transport of water across space and time is necessary and inescapable for a populous country like India. Of course, one should optimise the storage strategy through ground water recharge, small dams, ponds, or large reservoirs. All of them have a role to play.

Even run-of-the river schemes, which involve a tunnel from the weir to the turbine that can be few kilometres downstream, have environmental consequences. The stretch of river between the weir and the turbine becomes dry and its aquatic flora and fauna get affected.

The savings in net GHG emissions for hydropower might also be questioned. Fearnside has argued, based on a case study of Curua-Una dam in Para, Brazil, that the net GHG emissions in 1990 were three-and-a-half times the GHG emissions that would have resulted had the same electricity been generated using oil. He recognises that the situation would vary from project to project. On the other hand, a long-term study since 1993 funded by Hydro Quebec in Canada showed that GHG emissions from hydropower generation were only one-thirty-fifth that from gas-based generation. Of course, countries still may want to build storage reservoirs for water for cities and for irrigation.

Wind Power

Wind power requires marginal support as feed-in-tariff and can be set up quickly. The main problems are limited availability of wind resources and its low plant load factor. Thus, in India, the full development of its wind power potential of 65000 MW can supply no more energy than 20000 MW. Nonetheless, whatever potential is there should be exploited.

Solar Power

These countries have large potential for solar energy and it is a major long-term option. The main difficulty is its high cost. However, costs are coming down and some project it (KPMG, 2011) will reach grid parity in India by 2019. To reach this, however, requires strategic initiatives by the government. These involve setting a target to reach a certain scale to reap economies of scale, providing subsides in the interim in ways that encourage competition, cost- reduction and innovation. The reverse bidding where suppliers bid for subsidy required in the form of feed-in-tariff for solar power projects is one way to have market determined level of subsidy. Another way is to stipulate renewable portfolio standards to create a competitive market for different forms of renewables.

Absorbing Renewable Electricity

Wind and solar electricity are not available on demand. While solar power availability is predictable, that of wind power is much less so; hence, large-scale absorption of wind and solar power would require balancing power from hydro plants, pumped storage schemes, gas turbines, etc. Thus, at some stage, concentrated solar power with heat storage that can provide base load will begin to look more attractive. Another problem with many distributed wind and solar plants is the quality of grid required. A ‘smart’ grid will become necessary. The level of ‘smartness’, however, will depend on particular situations.

Renewable Energy for transport

While electricity will replace some of the liquid fuel required for transport, renewable options need to be developed. Brazil's programme of ethanol, based on sugarcane, and bio diesel, based on soybeans, has been a great success. However, the resources of land and water that Brazil has are not available to others. Second-generation ethanol based on cellulosic material, agricultural wastes and specially grown grasses can be an important option in future; at present, the technology is not economically viable. While ethanol is a renewable fuel, its GHG emissions benefits have been questioned. However, Moreira comments as follows:

"Production and use of bio fuels have been under criticism in the last 2 years due some new sustainability indicators. One of them is the bio fuel contribution to GHGs emissions due to direct land use (LUC) and indirect land use change (ILUC). Another source of concern was related with the significant release of N2O to the atmosphere due the use of N-fertilizers when planting bio fuels feedstock. Some authors tried to convince society that not all bio fuels are necessarily green (Searchinger et al, 2008, Fargione et al., 2008, Crutzen et al, 2008). But, all these evaluations conclude that sugar cane ethanol is one with the best capacity to mitigate climate change if properly managed (Gibbs et al, 2008, EPA 2010). Furthermore, more recent papers conclude that ILUC effects are important but they were initially overestimated. Also, N2O emissions from N-fertilizers shall be considered but the values quoted in the IPCC Guidelines are more modest and represent better the reality (see Mosier et al, 1998; Smeets et al, 2009 and Davidson, 2009).

According to US-EPA, ethanol from sugar cane produced in Brazil is able to reduce CO_{2eq} *emission by 61% considering LUC and ILUC effects (US EPA, 2010). Pacca and Moreira, 2009 tried to quantify the overall impact of the PROALCOOL program since its launching (1975) up to 2007….(They found) that in the initial years of the program, the overall effect was negative, increasing GHGs emissions, mainly due to C from above and below ground biomass lost to the atmosphere when converting earlier vegetation in sugarcane crops. It took 17 years for* CO_{2eq} *emissions avoided from gasoline, due its displacement by ethanol, to offset all the initial GHG emissions. Nevertheless, after 32 years it is possible to see that 125* tCO_{2eq}*/ha has been avoided. The relatively long offset time was a consequence of the very poor initial efficiency of ethanol production. By 1975, average ethanol yield was around 2,000 liters/ha, while today the average is above 7,000 liters and even higher than 9,000 liters for the best plantations. Furthermore, only after 1995 the use of bagasse for electricity generation and its sales to the grid took relevance. Another important consideration about the use of sugar cane is that more technology can still be added to the activity. Carbon capture and storage (CCS) is being suggested in the literature as an important option to mitigate climate change. When sugar is fermented to ethanol, almost the same amount of ethanol by weight is produced as* CO_2*. This extremely pure* CO_2 *and at 100% concentration, is usually released to the atmosphere. Its capture has been suggested*

(Mollersten et al, 2003, IPCC, 2005) as a potential low cost option, since all that has to be made is proper compression and underground storage, considering that capture is not necessary, because it flows out of the closed fermentation vessel as a pure gas, through valves."

6. Concluding comments

The review of renewable energy in these five emerging economies show the need to develop renewable options both because of concerns on climate change and the desire for energy security. These countries have promoted programmes consistent with their natural resources. Successful development of renewable resources requires targeted policies. These have to be designed carefully to promote cost reduction and innovation. These studies do show that significant potential exists for renewable energy. It will, however, take time and these countries need global environmental space to develop in the meanwhile.

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