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ENERGY EFFICIENCY AND ENERGY FROM RENEWABLES:
BRINGING MITIGATION AND ADAPTATION TOGETHER

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ABSTRACT: The production and consumption of energy, particularly fossil fuels, is the root cause of humankind's most significant environmental challenge, global climate change. By definition, how society changes its use of energy applies both to mitigation and adaptation strategies. It is unique in this sense, since many actions that address climate change are categorized as either mitigation or adaptation, and rarely as an integrated response. This paper explores the important role that producing and using energy in a more sustainable manner can act as an effective integrated response to climate change, specifically the role of energy efficiency and energy from renewables. It draws upon secondary and primary research and highlights similarities and differences in Canada and China.

Keywords: adaptation, energy efficiency, integrated response, mitigation, renewable energy

1. Introduction

The production and consumption of energy, particularly fossil fuels, is the root cause of humankind's most significant environmental challenge, global climate change. By definition, how society modifies its use of energy can apply to both mitigation and adaptation strategies. It is unique in this sense, since many actions that address climate change are typically categorized in the climate change impacts literature, in policy development, and even in the practice of stakeholder engagement, as either mitigation or adaptation, and rarely considered as an integrated or dual function response. While there are undoubtedly valid reasons for this separation, the establishment of "stovepipes" or "silos" around these actions may actually inhibit the development and implementation of a more integrated and effective response to climate change, particularly at the community or local level.

Generally, adaptation has taken a back seat to mitigation in the policy discourse on climate change, despite the fact that the former is also cited in the United Nations Framework Convention on Climate Change (Article 4.1) and the Kyoto Protocol (Article 10). Arguably, the climate change impacts literature has adopted a somewhat defensive tone, treating adaptation in isolation of mitigation, or at best presenting it as a necessary addition to measures to reduce emissions of greenhouse gases (e.g. Maxwell et al., 1997; Smith et al., 2001). Efforts to broaden the treatment of climate change adaptation have also ventured into the field of sustainable development (e.g. Cohen et al, 1998; Venema and Cisse, 2004), but its overlap and integration with mitigation measures remains the exception rather than the norm. Energy production and use is a good illustration of this dichotomy which needs to be redressed because a better integration of mitigation and adaptation measures could lead to a more effective and sustainable use of scarce resources. Renewable energy, for example, is more likely to be considered as a mitigation response to climate change and yet a combination of renewable sources may be more resilient than conventional large-scale centralized systems, especially to extreme weather events. However, this separation and lack of understanding regarding the dual benefits of some climate change measures is not restricted to energy. Indeed, a thorough inventory and assessment of measures that address both mitigation and adaptation has yet to be published, whether on a sectoral, regional or country basis.

This paper outlines how the more effective production and use of energy can play an important role as a sustainable and integrated response to climate change. At best, this paper is exploratory in nature, focusing on the role of energy efficiency and energy from renewables. It draws upon secondary and primary research and highlights similarities and differences in China and Canada, and in the latter case with special reference to the province of Ontario. The discussion begins by briefly outlining how mitigation and adaptation can and should be brought together through the example of energy. Issues such as greater energy security, reduced vulnerability of the electricity generation and distribution system, improved air quality and health, and an increase in rural employment, among others, are examined vis-à-vis energy efficiency and renewable energy. The next section describes the energy situation (especially electricity) in each country, in terms of its temporal and spatial dynamics, as well as the economic and political forces influencing supply and demand for current conditions and future scenarios. The environmental and health consequences associated with conventional energy sources and business-as-usual practices are then highlighted for both Canada and China. It also examines the economic, social and environmental co-benefits that could be achieved by adopting an alternative pathway of energy efficiency and low impact renewables. The discussion concludes by proposing a blueprint for energy efficiency and renewable energy in Canada, and discusses its applicability to the situation in China.

2. Mitigation and Adaptation

While the Kyoto Protocol is an important first step in reducing GHG emissions, the meeting of these targets by all signatories to the agreement will only slow down a doubling of carbon dioxide (CO_2) in the atmosphere by approximately 6 years. It is almost certain that some degree of climate change is inevitable, unless more significant emissions reductions occur. According to the IPCC Third Assessment Report, the stabilization of atmospheric CO_2 at concentrations around 500 ppmv, below what is considered currently to cause dangerous interference with human and natural systems, requires global anthropogenic emissions of GHG to be reduced by about 50 percent relative to current levels (Houghton et al, 2001). From a policy perspective this leads to two clear conclusions: 1. adaptation to climate change will be necessary; and 2. further reductions in GHG emissions beyond the Kyoto targets are needed.

Despite the fact that both mitigation and adaptation are required to deal effectively with climate change, each type of response tends to be treated separately at the national, regional and local level. Exceptions for an integrated approach include the broadening of mitigation actions to consider the co-benefits from improved air quality for environment and health, and the incorporation of adaptation measures into principles of sustainable development. The former is based on the fact that fossil fuel combustion generates emissions of air pollutants that cause a suite of atmospheric concerns, including climate change, acid deposition, hazardous airborne pollutants, and smog. Not surprisingly the co-benefits for environment and health from taking actions to reduce emissions of greenhouse gases plus other pollutants is a prominent feature in the climate change policy discourse, especially in areas where coal-fired plants are a significant contributor to regional air pollution and pose a serious health problem. The health benefits from improved air quality alone arising from GHG emission reductions of 10 and 15 percent below 1990 levels for developing and developed countries respectively could reach over 700,000 avoided premature deaths annually on a global basis (Lee Davis et al, 1997).

The integration of mitigation and adaptation measures however is less prevalent in the literature, especially in climate change impact assessments. In some cases the issues are presented jointly, but even then climate change science and the need for mitigation actions serve more as the context to address adaptation rather than presented as part of an integrated response (e.g. Smith et al, 2001; Standing Senate Committee on Agriculture and Forestry, 2003). Even the three IPCC Assessments have generally presented climate change in this manner (e.g. Smit and Pilifosova, 2001; Toth and Mwandosya, 2001). As a result, decision-makers are frequently left with little guidance in terms of developing an integrated response to climate change or evaluating mitigation measures vis-à-vis their contribution as an adaptation response and vice versa. The need for an integrated response may be most acute at the local level, where, in Canada for example, municipalities are directly and indirectly responsible for fifty percent of greenhouse gas emissions, and where there is limited knowledge about impacts and adaptive capacity. There is evidence, however, to suggest that tentative steps forward are beginning to be taken to address the integration gap. Just recently an integrated, collaborative approach to climate change adaptation has been initiated in the Regional Municipality of Halifax, with the intent of helping municipalities develop management and planning tools to adapt to climate change and reduce greenhouse gas emissions (Government of Canada, 2004).

In terms of the energy sector, the preponderance of research and policy initiatives has been directed at mitigation, with much less attention on impacts and adaptive capacity. This disproportionate attention towards preventing climate change from occurring may have been necessary to gain global commitment for mitigation targets, but now that the Kyoto Protocol is ready to be activated, the consequences of ignoring the vulnerability of the energy sector to climate change impacts needs to be assessed carefully. Such an imbalance is ill advised for energy planners and decision-makers, since there is growing evidence that the impacts of climate change on the energy sector can be significant, not only for exploration and resource extraction, but also for electricity generation, transmission/distribution, and demand (Street et al, 2002; Mirza, 2004). Furthermore, the focus on one type of response overlooks the potential for identifying and implementing actions that address both mitigation and adaptation needs. This could lead to the inefficient use of scarce resources, and missed opportunities to capture a wide range of co-benefits.

The linkage of adaptation to mitigation issues has been addressed in some cases, specifically in the context of how various emission reduction policies (to both climate change and air quality) and population/economic growth scenarios may affect the future energy mix, which in turn could be impacted by climate change (Lin et al, 2004). The latter research effort, which has focused on energy supply, generation, transmission and use at the regional scale, has engaged stakeholders through surveys, interviews and numerous workshops. It has advanced an integrated approach recognizing that the future energy mix will be determined more by emission reduction policy considerations rather than by climate change impacts. However, it still falls short of providing a comprehensive assessment of conventional (nuclear, fossil fuel, and large-scale hydro) and low-impact renewable energy options vis-à-vis their dual mitigation and adaptation functions.

3. Energy Systems and Challenges – China and Canada

China and Canada have significant differences in population size, economic output and energy resource distribution; however, both face substantial challenges for energy production and use. Most of these challenges, whether shaped by geography, economic, political, social and environmental factors, are unique to China and Canada, but many are also common to both countries. Both China and Canada, in the latter context especially the province of Ontario, are facing energy and electricity shortages, requiring greater consideration of energy efficiency measures and the expansion of renewable energy.

3.1 China

Energy plays a crucial role in any economy, and is key to China's continuing rapid economic growth and efforts to alleviate poverty. Although blessed with a wealth of natural resources, China is typically considered to be "energy poor", given its expanding economy, population size, and low per capita energy consumption. In recent years the Chinese economy has been growing by approximately 9 percent annually, while its population is reaching 1.3 billion and is increasing at about 10 million each year. Although per capita energy consumption is about one-sixth that of OECD countries, China ranks as the second largest energy consumer and producer in the world, behind only the United States.

From 1980 to 1996 the centrepiece of each of China's 5-year economic plan has been the expansion of energy production, in part responding to more than a doubling in primary energy use over this period. While energy use declined slightly from 1996 – 2000 during the Asian economic recession, since 2000, energy use has increased again and is expected to grow by over 3 percent annually between 2005 to 2015 (Asia Research Centre, 2001). Increases in the standard of living, rising incomes and the continued exodus of rural-to-urban migration are expected to drive much of the demand for electricity. In 1990, net electricity consumption in China was 551 Terra Watt-hours (TWh), rising to 1,312 Terra Watt-hours by 2001 (EIA, 2003). Given the complex dimensions of the factors determining energy supply and demand, it is difficult to forecast future scenarios accurately, especially for a rapidly emerging economic giant such as China. There is little dispute, however, regarding the overall direction and general magnitude of future conditions. Assuming an average annual percent change of 4.3, for example, net electricity consumption is projected to reach almost 3,600 Terra Watt-hours by 2025, representing more than a 6-fold increase from 1990.

China relies heavily upon conventional sources of power for its energy and electricity needs. More than 60 percent of China's primary energy consumption is derived from coal, and the country has sufficient reserves to meet demand at current levels past 2100. Domestic oil reserves have been declining since the mid-1990's, resulting in an increase in imports and some substitution with natural gas. In the latter case, residential use has been increasing steadily, especially in large urban centres, in an effort to reduce harmful emissions causing air pollution. While electricity use has been increasing substantially, approximately two-thirds is generated by coal-fired power stations, with hydropower generating about one-quarter and the rest from oil and nuclear. At best, China's economy can be described as a highly inefficient user of energy, especially in the heavy industry sector. In the late 1970s, specific economic and conservation policies were introduced to improve energy efficiency, which led to significant energy savings. By 2000, China had reduced its energy use per unit of GDP to half of what it consumed in 1980; however, the room for improvement continues to be large. In order for its industrial sectors to meet international energy efficiency standards, China needs to further reduce energy use by 30 to 50 percent (IEA, 2000). Although energy efficiency can go a long way towards reducing GHG emissions, with economic development expected to continue at a fast pace, efficiency measures alone will be insufficient to control GHG emissions from the energy sector (Metz et al, 2001).

With the world's fourth largest land mass of 9,596,960 square kilometers, geography plays a significant role in China's energy production and use, particularly in terms of resource distribution and distance to markets (McCreary et al., 1996). A majority of fossil fuels are found in northern areas, yet much of China's rapid economic growth has occurred in the south and along its eastern coastal regions. Significant energy transportation problems exist in terms of inadequate support infrastructure and limited rail freight capacity. The latter has been especially problematic for coal, resulting in the higher production and use of more accessible but extremely low-grade deposits in the south, compared to the less accessible but higher-grade deposits in the north. China has the world's largest hydropower generating potential in the world, estimated at 379 Gigawatts (GW); however, much of this potential is at sites located within the Himalayan mountain ranges in the southwest, which are also far from major centres of population and economic activity. Even if all exploitable hydropower resources were developed, while more than 1,900 Terra Watt-hours could be generated, an amount three times the electricity China produced in 1990, this amount would still represent only about one third of projected capacity for the year 2015. Nuclear power capacity is about 2 Gigawatts, which amounts to only 1 percent of China's current total electricity use. New plants under construction could quadruple nuclear output by 2010, but this will still likely only contribute a small fraction of total electrical generating capacity. In 2001, renewable energy (geothermal, solar, wind, and wood and waste) generated 1.9 Terra Watt-hours, a negligible amount of China's net electricity generation (EIA, 2002). Generation capacity from windfarms was less than 400 Megawatts (MW).

Due to its relative abundance, coal is expected to feed the growth of electricity generating capacity for many years. This dependency on coal, however, has come at a significant environmental and social cost. China is the world's largest producer of sulphur dioxide emissions, and the second largest emitter of carbon dioxide. A report released in 1998 by the World Health Organization noted that seven of the ten most polluted cities in the world are in China, due largely to emissions of sulphur dioxide and particulate matter from coal combustion (WHO, 1998). The report also estimated that acid deposition falls on 30 percent of China's total land area. Further, the impacts of air pollution on agricultural production and human health may be so severe that up to 10 percent of China's gross domestic product may be lost each year (Johnson et al, 1997).

Despite the challenge of providing energy for a growing economy and the associated costs of burning coal, there are positive signals that the Chinese government is prepared to take action towards cleaning up the environment. In their tenth five year plan (2001-2005), for example, the Government of China emphasized clean energy, technological upgrading of the energy industries, and energy efficiency over the more traditional structural adjustment of expanding energy production. China's energy priorities seem to be moving towards clean coal, natural gas, nuclear and to a lesser extent renewables. Furthermore, in July 2004, the Chinese State Council (akin to cabinet) approved a draft of China's Energy Development program for 2004-2020, with energy conservation and efficiency as its top priority. Continued rapid economic growth and one of the most serious periods of energy shortages since the 1980s is placing an urgent emphasis on the potential for energy efficient measures.

In recent years the electricity sector has also undergone considerable reform, moving from a state-owned centrally controlled system to a more deregulated, decentralized and market oriented system. Under the previous system, the coal industry enjoyed a history of being heavily subsidized, and energy reforms are considered a necessity to create a market in which renewable energy can become more competitive. However, the wind power and renewables industry tends to be much more controlled by government than other sectors of the economy. The potential of renewable energy resources for electricity is substantial in China, with wind power, for example, capable of achieving 250 Gigawatts of installed generation capacity (Brown, 2002).

3.2 Canada

In Canada, energy also plays a key role in the national economy, and contributed to over 6 percent of GDP in 2002. Despite having a comparatively small population of just less than 32 million in 2001, Canada is an energy intensive country, with one of the highest per capita consumption rates in the world (National Energy Board, 2003). Canada has abundant energy supplies, including the oil sands. Approximately 50 percent of the natural gas produced in Canada is exported to the United States. On a national basis, electricity generation is dominated by hydro. With an installed capacity of 67,000 Megawatts, Canada is a world leader in its use. Approximately 60 percent of Canada's electricity is generated by large-scale hydro, with coal, nuclear, natural gas and oil contributing 18, 13, 4 and 3 percent respectively.

Small-scale hydro and other renewables contributes less than 3 percent. Barely 440 Megawatts is currently generated by wind power in Canada.

Net electricity consumption was 435 Terra Watt-hours in 1990, reaching 504 Terra Watt-hours by 2001 (EIA, 2003). Assuming a business-as-usual average annual change of 1.9 percent, electricity consumption is expected to rise to almost 800 Terra Watt-hours by 2025, reaching a level just below double from 1990. Electricity production and use varies considerably across Canada, as both resources and technologies are unevenly distributed. Some provinces, such as Quebec and Manitoba, rely principally upon hydro, while others such as Nova Scotia, Saskatchewan and Alberta rely primarily upon coal. Ontario is perhaps unique in this regard since electricity generation is distributed across nuclear (36 percent), hydro (25 percent), coal (25 percent), and oil and gas (14 percent). Renewable energy (wind power) contributes only 0.2 percent of the provincial electricity capacity.

Ontario presents a significant energy and electricity challenge for many reasons. The province is one of two (the other is Alberta) in Canada that has recently introduced reforms in the electricity sector, moving away from a monopoly run system towards an open market. Price volatility is now the norm, for both electricity and natural gas, which is raising some concerns regarding economic competitiveness and affordability. Ontario has the largest population in the country, and contains Canada's industrial heartland. Although the provincial electricity system has its roots in hydropower, since the early 1970s it has become increasingly dominated by a pro-nuclear and pro-coal culture. There is growing concern about costly price overruns on refurbishing ageing nuclear facilities, and increasing environmental and health concerns around coal-fired power plants. In the latter context, electricity generation from coal is a major source of sulphur dioxide, nitrogen oxides, and other air toxics such as mercury, contributing to acid deposition, smog and emissions of hazardous air pollutants. Their contribution to local air pollution has attracted considerable attention from environmental groups and the public health community, which have been campaigning vigorously to have them phased out. A recent report has estimated that air pollution from all sources is responsible for 1,700 premature deaths and 6,000 hospital admissions annually just in the City of Toronto (Campbell et al, 2004). Another study has estimated the economic and social costs for Ontario to be about $1 billion per year (Ontario Medical Association, 2000). Coal-fired plants are also a major source of GHG emissions, and their phase out would make a substantial contribution to Canada's Kyoto target of 6 percent below 1990 levels by 2010. The current government has promised to phase out coal generation by 2007.

Existing installed generation in Ontario is about 30,500 Megawatts, although in practice normal weather peak demands rarely exceeds 24,000 Megawatts. Even at this amount, however, there is limited excess capacity and the Independent Marketing Organization often has to import power from other provinces and the U.S. during periods of peak demand. Without significant conservation efforts, energy consumption is forecast to grow from about 156 Terra Watt-hours in 2005 to about 169 Terra Watt-hours in 2014, based on an average annual growth rate of 0.9 percent (IMO, 2004). Summer peak demands are projected to exceed 26,600 Megawatts by 2014. If coal is phased out by 2007 and nuclear facilities are retired by the end of the next decade, Ontario could be facing a significant shortfall between electricity supply and demand. Even if proposed generation projects are completed in a timely manner, which would add about 6,000 Megawatts of new supply mostly from natural gas, aggressive conservation measures will be required, as well as additional generation capacity from new supply or refurbished generation. While electricity could be imported from hydro sources in Quebec and Manitoba, this would require substantial investments to expand the transmission infrastructure. For long-term reliability, planning would have to include higher construction standards to minimize projected climate change impacts on the grid (Mirza, 2004).

An opportunity therefore exists for considerable expansion of renewable energy and energy efficiency measures. The provincial government has recently announced renewable targets of about 1,350 Megawatts by 2007 and 2,700 Megawatts by 2010. A recent RFP (request for proposals) issued by the provincial government for 300 Megawatts from renewables attracted forty final proposals that would, if constructed, collectively add more than 1,100 Megawatts of electricity capacity by 2010. But there is the potential for much more in the future. The theoretical potential for Canada's green power resources is at least 340 Terra Watt-hours, or more than half of the current annual electricity generated in Canada (Pollution Probe and Summerhill Group, 2004). In terms of energy efficiency measures, Winfield et al (2004) have estimated that the adoption of best practices throughout the economy could result in electricity use dropping by 40 percent below business-as-usual forecast for 2020. Such a target may be achievable given Canada's historical performance. Energy productivity gains in Canada from 1970 – 1998 were greater than increases in primary energy use in all sectors (Torrie et al, 2002). Between 1990 – 2002 alone, improvements in energy efficiency saved 880.7 Petajoules of energy and 49.9 Mt of GHG emissions (Office of Energy Efficiency, 2004).

4. Potential and Benefits of Energy Efficiency and Energy from Renewables

While adopting energy efficiency measures and increasing the amount of energy and electricity from renewable power have obvious mitigation implications, their adoption also has considerable co-benefit potential for environment and human health. The analysis of co-benefits has received considerable attention in the climate change literature, and while most studies are not intended to defend or justify GHG mitigation actions on this basis, they do illustrate the additional benefits that could be realized if appropriate actions are taken. Among the various mitigation options, electricity generation and energy efficiency in residential and commercial buildings have been identified as two key areas where considerable co-benefits could be realized (Chiotti and Urquizo, 1999). A preliminary assessment of air quality co-benefits from climate change mitigation actions conservatively estimated for Eastern Canada that a suite of measures, including reductions from coal-fired power plants, would lead to 92-150 avoided annual mortality by 2010, and reduced health care costs of $300 - $500 million (EHI, 2000).

Studies on the co-benefits from energy efficiency are less common. While such measures would also help reduce emissions of greenhouse gases and other air toxics, there is also the potential for more localized benefits to be realized, including strengthening adaptive capacity. For example, some cities are promoting the use of green roofs, in which gardens are installed on building rooftops as an integral part of the roofing system. The green roofs can help reduce the urban heat island effect, which can result in illness and even deaths, thereby contributing to the process of adapting to warmer summers. At the same time, green roofs can help reduce air conditioning use that results in a reduction in emissions of GHG's and other air pollutants from coal-fired power plants. Further, green roofs can help filter out air pollutants, act as a buffer in storm water management and offer other benefits such as providing wildlife habitat, offering new economic opportunities, and increasing property values (Bass and Baskaran, 2003). Other energy efficiency measures could also perform both a mitigation and adaptation function, while improving indoor air quality and human health. New homes modeled on R-2000 standards, for example, have been found to achieve significant energy savings (from 35 to 49 percent reductions in electricity, natural gas and oil consumption), while reducing GHG emissions associated with fuel consumption by an average of 39 percent (Lio and Associates, 2003). To address the need for ventilation in R2000 homes, due to the more air-tight construction used for greater energy efficiency, the homes use heat recovery ventilators that not only reduce the condensation associated with air-tight homes, but offer cleaner indoor air for a healthier environment. A recent study by Leetch et al. (2004) found that the occupants of new energy efficient homes (which met R-2000 standards) experienced lower incidence of throat irritation, coughing, fatigue and irritability.

While renewable energy is more likely to be considered as a mitigation response to climate change, it can also perform an adaptation function. A combination of renewable sources can often be more reliable and resilient than conventional large-scale centralized systems, and in the case of climate change a diversified system could be more adaptable to extreme weather conditions. The 1998 ice storm and the August 2003 blackout, for example, clearly demonstrated both the vulnerability and limited adaptive capacity of conventional generation and the transmission grid in North America. In the case of China, an added consideration may be the impact of renewable energy expansion on employment and rural development. An established wind turbine manufacturing industry, for example, creates about 40 percent more employment compared to coal per dollar of investment. In the U.S., a recent study has estimated that strategic investments in clean energy and efficiency would create 3.3 million new, high-wage jobs (Institute for America's Future and The Center on Wisconsin Strategy, 2004). The expansion of renewables into rural China, such as household biogas digesters, could also help replace the use of traditionally burned coal in unvented firepits, which is known to increase the risk of lung cancer (Lan et al, 2002), and has other hygiene and agricultural productivity benefits. The most significant co-benefits, however, could be realized in polluted urban centres. In Shanghai, for example, a combination of improved energy efficiency and the introduction of natural gas could lead to 647 – 5,472 PM_{10} related avoided deaths by 2010, and 1,265 – 11,130 by 2020 (Gielen and Changhong, 2001; Changhong et al, 2001).

The broader implications of shifting energy supply from conventional sources to less polluting alternatives are perhaps best defined in the context of developing countries and decentralized renewable energy. Venema and Cisse (2004) propose that decentralized renewable energy projects should be a fundamental priority of sustainable development and also represent an example of an integrated mitigative and adaptive response to climate change. The link to adaptation extends well beyond the energy sector, suggesting that more equitable access to energy supplies will help stabilize the social and ecological determinants of climate change vulnerability. This implies that some energy measures may not in themselves be considered as a direct climate change adaptation strategy, but can nonetheless indirectly function as an essential prerequisite for building adaptive capacity. In the case of decentralized renewable energy, while their adoption may serve a mitigation function, they will also contribute to a number of positive sustainable development outcomes, such as:

- assisting the sound and equitable management of biodiversity and ecosystems;
- improving access to safe water and sanitation services;
- improving air quality and limiting exposure to toxic chemicals; and
- reducing and mitigating natural disasters and resource-based conflict.

Adopting environmentally sound energy systems can also help alleviate poverty, reduce child mortality and promote gender equity (Reddy et al, 1997). Improved access to energy services, especially high quality fuels and cooking technology, has a direct impact on the health of children. For example, in many rural communities chronic exposure to harmful airborne pollutants often occurs at the household level among women and children, due to biomass combustion using primitive, inefficient stoves indoors (Smith, 1993). Energy efficiency measures can be described in a similar manner, enabling society to live better, pollute less and deplete fewer resources, create income and jobs, multiply the use of scarce capital, and increase security (Van Weizsacer et al, 1997). When done properly, energy efficiency measures applied in residential and commercial buildings can also help improve indoor air quality, and subsequently lead to improved human health and well being.

5. Towards a More Sustainable Energy Future

This paper has attempted to demonstrate how the more effective and environmentally sensitive production and use of energy, specifically renewable power and energy efficiency, can play an important role as a sustainable and integrated response to climate change. Renewable power in both countries are not merely a niche market, and combined with energy efficiency can help address regional and global environmental challenges, while still meeting domestic economic needs. In the absence of a fully developed and comprehensive integrated energy strategy in the climate change literature, however, it may be prudent to look elsewhere for direction and guidance in terms of moving forward towards a more sustainable energy future. In this case *A Green Power Vision and Strategy for Canada* may be a good place to start (Pollution Probe and Summerhill Group, 2004). A thorough assessment of renewable energy options and energy efficiency measures in terms of their applicability as mitigation and/or adaptation actions is needed. This would require consideration of a broader range of benefits that have been identified for green power (see Figure 1). Enhanced adaptive capacity would likely contribute to energy security, electric power grid stability, rural development, and job creation, among others. Energy efficiency would also contribute to most of these categories.

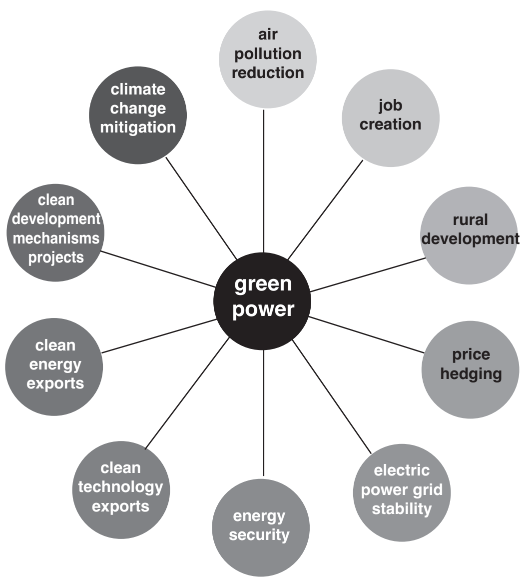

FIGURE 1

Green Power Benefits

From a policy perspective, it will be important to focus on three priority areas if progress is to be made on guiding and accelerating the development of renewable energy and energy efficiency. First, it will be necessary to level the playing field, which currently favours the conventional centralized energy systems for electricity generation. Historically, billions of dollars have been invested to develop oil, gas and nuclear power to ensure reliable and low-cost supplies of electricity – it is time to invest in renewable energy sources in the same way. It will be necessary to invest in innovative technologies for renewable energy and energy efficiency to ensure future market readiness for emerging technologies. Support for such innovative technologies could also enhance each country's potential to develop expertise in these areas and market the knowledge and technologies worldwide. Long-term opportunities for renewable energy both domestically and abroad look promising as the capital stock of the global energy system is expected to turn over at least twice by 2100 (Painuly, 2001). Whereas Canada is facing the need to replace aging conventional generating stations, China's rapid economic growth presents them with the opportunity to adopt cleaner green technologies from the outset. Lastly, it will be necessary to engage a wide range of decision-makers and the public in achieving this vision, particularly at the community level. While community engagement is considered an essential piece of the Canadian strategy, its application to China may be more problematic. As Brown (2002) notes, how quickly energy from renewables penetrate energy markets in China will depend in part on consumer pressure but more so on government policy and regulatory support, which depends on broader energy, industrial and environmental objectives.

In the case of China, the solution may be to build on the trend of decoupling economic growth from energy consumption and adopt a normative approach to energy production and use, that accepts economic growth as a necessary but not a sufficient condition. As Goldemberg et al. (1988) suggest, the fundamental goals of society should be equity, economic efficiency, environmental harmony, long-term viability, self-reliance, and peace. Energy production and use should be compatible with these societal goals, which applies to both developing and industrialized countries, as well as having implications for the relationship between them and within the global community. China's efforts and success to reduce energy use and emissions of air pollutants is not only a domestic concern, but also a key factor in international environmental relations. With continued economic growth and the world's largest population, China will soon surpass the United States as the world's largest emitter of CO_2 emissions. It is therefore in Canada's interest not only to support China's efforts to develop a more sustainable energy system, but also to lead by example by taking action on a vision and strategy that promises a more sustainable domestic electricity future through energy efficiency and energy from renewables. By doing so, both countries will not only help reduce harmful emissions of GHG's and other pollutants, but also strengthen their adaptive capacity to climate change impacts.

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