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analyses

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Bringing Developing Countries into the Energy Equation

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Contents

For almost two hundred years, the economic development of industrialized countries has gone hand in hand with growing consumption of fossil fuels, first coal, then oil and gas. The oil shocks of the 1970s had already revealed the fragility of this model, without however generating any major changes. The disconnection observed in the 1980s between a rapid return to economic growth and stagnating energy consumption was only provisional, and energy demand in the richest countries has again been rising since the 1990s; the development of alternative energy sources (nuclear power and renewables) has remained marginal and has failed to dethrone fossil fuels on which, paradoxically, the economies of industrialized countries are even more dependent today than they were 20 years ago.

But with the turn of the century came major developments in the global energy landscape following the emergence of new and hitherto marginal actors: the rapid economic development of emerging countries is also dependent on an increasing supply of energy. Today this growing demand adds to tension on the oil and gas market, where the poorest countries are also the first victims. It could give new impetus to the development of alternative energies; but according to experts, growth in energy will first and foremost concern coal.

These developments are of course wholly paradoxical and cause for concern at a time when the international community is looking for ways to continue the effort begun collectively in 1992 to mitigate climate change. First, they appear to confirm those who – especially in Rio –stressed the need for industrialized countries to accept to submit the energy models of their growth to a radical reassessment. Second, they largely invalidate the idea that growing tension on oil and gas markets automatically leads to climate change mitigation. Third, they underline the urgency of encouraging emerging countries to act, while revealing the difficulties involved. The emissions due to fossil fuel consumption are by far the primary cause of climate change. But when geographers and economists view energy consumption as a sign of wealth, it is not surprising that developing countries are concerned about the potential impact of greenhouse gas emission limits on their economic growth.

The contributions included in this publication first take the opposite view by showing why this 'law' may be no more than a historical accident, and under what conditions a very different relationship could be established between development, energy consumption and greenhouse gas emissions. It follows that discussions on a 'future regime' for mitigating climate change must explicitly allow for progress in reforming our energy model, and provide an action framework suited to the situations of the different groups of countries. From this viewpoint, the recent experience of the mechanisms introduced in Kyoto provides essential indications concerning the indisputable value of these instruments, but also their shortfalls. The last three contributions explore the implications of taking better account of the necessary policies and measures on the architecture of a future climate change regime.

Michel Colombier
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Today the threat of climate change is rapidly raising awareness of the unsustainability of increasing energy consumption. Given the deadlock reached by traditional energy policies, which focus on supply, a new model centered on energy service needs is emerging. It is leading to a global energy conservation strategy, a sine qua non condition for the reduction of global greenhouse gas emissions.

Energy in the world: Challenges and prospects

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Satisfying growing socio-economic needs – a condition of development – seems to result in an inevitable increase in energy consumption. Despite significant differences between regions, sectors and types of resource that merit attention, a clear and regular increase in world energy consumption has been observed, with all the ensuing consequences for public health and the environment, especially the risk of global warming.

Projections made based on trends observed over recent decades are not sustainable: due to the finite nature of fossil resources and the need to limit greenhouse gas emissions, energy strategies must be redirected. Is there an alternative to the deadlock reached by 'business as usual' policies? Energy forecasts propose a solution based on a shift in perspective: analysis must no longer be based on energy supply solutions but rather on the energy services needs that must be satisfied.

From energy needs to primary resources

The development of a society implies the growing satisfaction of a certain number of socio-economic needs: food, housing, health, clothing; facilities for transporting people and goods; the production of goods and services; education, information, culture, the exercise of civil rights, sports and leisure; the quality of the natural environment, etc.

Satisfying these needs requires varying degrees of energy consumption, whether for direct use in certain cases, or for producing the associated goods and services: farming, cattle rearing, fishing; preparing, preserving and cooking food; lighting, heating or cooling housing, workshops, offices and shops; producing and processing raw materials, generating and transforming energy; constructing buildings and infrastructure; manufacturing equipment and machinery; transport systems; means of information and communication, etc.

Several 'energy chains' may correspond to each socio-economic need, with each chain representing the journey from this socio-economic development need – which can only be satisfied if a certain amount of energy is consumed – to the basic energy resource enabling the user to be supplied with this energy. The chain depends primarily on the kind of energy directly used: heat, cold; fixed or mobile propelling force; light; electromagnetic energy; or chemical energy. This 'useful' energy is that which is delivered by the user's energy equipment or appliances: boilers, ovens, stoves; lamps, domestic or electronic appliances, computers; motors; industrial processes.

The 'final energy' stage corresponds to energy products delivered to consumers and consumed by their equipment: fuels and oil; district heating; electricity. In some cases, the final product may undergo only a slight transformation (as with natural gas); in most cases the final product is the result of a conversion carried out by the energy industry: this is the case for electricity produced by fossil fuel power stations and fuel made from oil in refineries. This transformation is generally associated with energy being transported by means of networks (oil and gas pipelines, power lines) or vehicles (oil and gas tankers, trains, trucks).

Upstream from this transformation is the 'primary energy' stage, corresponding to energy in its natural form: chemical energy contained in fossil resources (coal, oil, natural gas) or in the biomass (wood, plants, waste); mechanical energy from water or wind (hydraulic or wind power); thermal energy from hot water in the subsoil (geothermal) or the sun's rays; photovoltaic solar energy; nuclear energy from the nucleus of the uranium atom, etc. A distinction is generally made between fossil, fissile and renewable primary sources.

Energy consumption in the world

Energy consumption throughout the world has very different characteristics depending on the period, the sector and the region[a]. In 2004, global final energy consumption stood at 7 893 Mtoe and primary energy consumption at 10 485 Mtoe, for a world population of 6.34 billion people. The difference between primary and final energy is due to self-consumption in the energy sector, to losses during transport (power grid, gas pipelines) and especially to losses caused when heat is converted into electricity in thermal power plants (conventional or nuclear).

Despite the shifts observed following the oil shocks of 1973 and 1979, the overall appearance of global energy consumption over recent decades is a linear increase, with a sharp acceleration since 2000, which will be explained further on.

The three sectors that consume the most final energy in global energy balances are:

- industry, which represented 28% of total consumption in 2004 and has increased relatively little since the late 1970s;
- transport (27%), which has almost doubled in absolute terms since 1970;
- the residential and tertiary sector[b], the largest in terms of consumption (34%).

These global averages vary according to the level and the structure of the economy: for the CIS, the share of industry was 42% in 2004, compared to 14% for the transport sector.

Oil products remain predominant in end-use (43%), although their share has decreased over the last 35 years in favor of gas and electricity. Oil also remains the dominant form of primary energy (35% in 2004), followed by coal (25%), which, after a relative stagnation in the 1980s, is climbing again. The source of energy whose contribution has increased the most over the last 30 years is natural gas (21%). Biomass (wood, plant and animal waste), still used essentially in traditional techniques, holds an important place (10%), slightly above primary electricity (hydraulic and nuclear); the contribution of 'primary' heat (geothermal and solar) is very low.

World electricity production has increased by 230% in just over 30 years (17 370 TWh in 2004 compared to 5 250 TWh in 1971). In 2004, 67% of this electricity was generated by fossil fuels, 17% by renewable energy (96% of which was hydraulic) and 16% by nuclear energy. Since 1971, coal has been the leading fuel, with steady growth that has been gaining speed – it is the principal agent of the increase in consumption observed since 2000. The contribution of oil has significantly dropped in favor of gas (essentially natural gas), with the emergence of combined cycle power plant technologies and progress in cogeneration. The contributions of nuclear and hydraulic power are of the same order and have been relatively stable in absolute terms since 1990, after a significant increase in nuclear power between 1970 and 1990.

Contrasting regional progress

The evolution of primary energy consumption across all continents is highly significant. Consumption in all industrialized countries – North America, the CIS and Europe –, which stood at 71% of the total in 1971, represented only 54% in 2004. It has risen little in absolute terms, and has even decreased in CIS countries as a result of the economic slump that followed the dissolution of the USSR in 1990. Asia's consumption, on the other hand, has tripled and constitutes the main part of the global increase since 2000.

These 'global' figures hide major disparities. The OECD and CIS countries – home to some 1.44 billion people – consumed 6.49 billion toe in 2004, essentially in the form of commercial energies. Conversely, the 4.9 billion inhabitants of developing countries consumed 4.6 billion toe. There are also major disparities within this group: around 3 billion people (in the richest countries and the major cit-

Box 1

Energy accounting

The official unit of measurement for energy is the joule. Another measurement, and not only for electricity, is the kWh: 1 kWh = 3.6 MJ (or million joules).

For the sake of convenience, the production and consumption of primary and final energy are expressed using a common unit, the ton of oil equivalent (the toe and its multiple, the Mtoe, the million toe): 1 toe = 41.8 GJ (or billion joules).

Accounting for fossil fuels (or wood) using toe is simple: toe equivalences are calculated using the calorific values of these different energy products. However, oil production is often expressed in barrels: 7.3 barrels = 1 ton of oil.

Electricity is measured in kWh (or in TWh, billion kWh). To convert kWh into toe, international statistical systems have adopted the equivalent in physical units for electricity end-use: 1 000 kWh = 0.086 toe.

One particularity of international energy accounting concerns so-called 'primary' electricity accounting: hydraulic, nuclear, geothermal, wind and solar. For nuclear energy, heat produced by nuclear reactors and used to generate electricity is counted as primary energy, or 0.26 Mtoe per TWh produced. For hydraulic, wind or solar power generated without a thermodynamic cycle, the thermal equivalent per joule effect of the electricity produced is counted as primary energy, or 0.086 Mtoe per TWh. For an identical final energy output, the latter are therefore counted in the international system at a third of the value of nuclear energy in primary energy balances expressed in toe.

Given these difficulties, it is advisable to use the kWh when talking about primary electricity production.

ies or industrial centers of certain others) consume 3.6 billion toe of commercial energy, while 2 billion people (rural or peri-urban areas) consume 1 billion toe of conventional energy (biomass). Thus, almost one third of the world's inhabitants have no access to modern energy sources and almost 75% of the population of the planet uses only 40% of all energy consumed: supplying energy to this population, even at a low level, remains one of the key energy-related challenges throughout the world. In the face of this demand, energy crises, such as the oil shocks that have hit Western economies, have been of a temporary nature. The foremost energy crisis in the world concerns fuelwood and the countries worst hit by increasing oil prices are not rich, industrialized ones, but rather developing countries, which devote a proportionately much larger share of their meager resources to importing oil products.

Disparities in per capita consumption and energy intensity

Average per capita energy consumption has greatly increased over the last 35 years, despite fluctuations linked especially to oil shocks and their repercussions. Disparities in per capita consumption remained considerable in 2004, varying between 7.9 toe per year for the United States and 0.43 toe per year for sub-Saharan Africa (excluding South Africa). These disparities are even greater where electricity consumption is concerned: in 2003, average annual per capita electricity consumption was 8 000 kWh for the OECD and 450 kWh for India.

In addition to per capita energy consumption, 'energy intensity' is measured, in other words the relationship between energy consumption and gross domestic product, which is calculated using purchasing power parity (PPP) in order to take into account differences in the standard of living. This indicator describes the degree of energy efficiency of a country or a development model: it measures the quantity of energy consumed for a given level of comfort or production. Energy intensity evidently depends on factors such as climate (heating requirements) and on economic structure (the proportion of heavy industry). However, when countries of similar economic structure are compared, the essential factor is the efficiency of energy production and consumption: in short, the lower the energy intensity, the higher the efficiency[1].

The trend since 1971 has been a reduction in energy intensity. This fell overall by 29% in the OECD between 1980 and 2004. This fall is partly linked to structural change (less heavy industry and less industry in GDP), and partly to increasingly efficient energy consumption. The example of China merits special attention, where energy intensity has significantly decreased since 1971. Care must be taken when interpreting old figures, but there is no doubt that structural economic change has played a large part in this fall, with progressive industrial modernization and the growing share of manufacturing. But the risk is that this country may fail to take advantage of it economic growth to further reduce its energy intensity (an increase has been observed in recent years).

Russia (and the whole of the CIS) remains by far the largest consumer of energy for its GDP. After an increase during the economic slump of the 1990s, energy intensity has been decreasing since 2000, but remains very high: in 2004 it was three times higher than that of the European Union.

Carbon dioxide emissions

The rise in carbon dioxide (CO_2) emissions caused by the consumption of fossil fuels is the main cause of the increase in greenhouse gases at the global level. In 2004, global CO_2 emissions linked to energy activities stood at 6.7 Gtce, 51% of which came from OECD countries.

Like energy consumption, per capita emissions vary greatly from country to country, as does the relationship between CO_2 emissions and GDP . In view of international debates concerning the mitigation of climate change, it is interesting to note that CO_2 emissions produced by the EU-25 increased slightly between 1990 and 2004 (from 0.98 to 1.04 Gtce), while those produced by the United States increased from 1.31 to 1.55 Gtce over the same period. There are considerable differences in the value of per capita emissions: 2.26 tce for the European Union compared to 5.26 tce for the United States and 0.95 tce for China.

Energy prospects and challenges

The history of energy[2] can be used to develop projections . Every year the International Energy Agency (IEA) publishes the World Energy Outlook, which is produced as a means of analyzing needs and resources and pursuing current policies of States and companies (the 'business as usual', or BAU scenario). From a methodical viewpoint, the models are essentially based on econometric relationships (adjusted according to past trends) and on the impact (on supply and demand) of energy prices. This method has its limits and cannot be used to look too far into the future. Moreover, it focuses primarily on energy supply and provides little information concerning demand. The IEA outlooks are nevertheless considered as a reference, reflecting the OECD's official line.

In the 2030 projection published in 2005, the IEA predicts a 1.8-fold increase in primary energy between 2000 and 2030, reaching 16 Gtoe. Within this average yearly growth of around 1.4%, the IEA predicts a greater increase for natural gas (2.1% per year), but lower for nuclear power (0.4% per year), and real but moderate progress for renewable energy (6.2% per year). Consumption in OECD countries sees a 1.4-fold increase and global carbon emissions a 1.6-fold increase. Growth in production goes hand in hand with massive investment in the energy sector (for supply), reaching 16 000 billion cumulative dollars between 2000 and 2030, of which 60% in electricity.

Towards a radical transformation of the energy sector

The outlook described by the IEA is synonymous with fundamental changes in the structure of global energy demand, at both the geographic and the sector level. Thus, 62% of the increase in energy consumption will be down to developing countries, whose share will increase from 30% today to 43% in 2030. China will take the lion's share, creating almost one third of the total increase for all developing countries, followed by India and Brazil (5% each). Chinese consumption in 2030 will be equivalent to that of Europe at the same time, or to that of North America at the moment.

Transportation and captive electricity uses are expected to make the most rapid progress (moving respectively from 29% and 18% today to 33% and 22% of final energy consumed in 2030), with heat demand seeing more moderate growth. The energy scene for 2030 as proposed by the IEA, would thus be a world in which quasi-captive uses of oil would have significantly increased, despite the risk of depleting resources, and where global efficiency would be diminished[c], despite the threat of climate change.

The most interesting thing about this outlook is that the IEA itself considers it untenable. During the presentation of the report in July 2005, its deputy executive director, William C. Ramsey, said that these projections have serious implications and lead to a future that is unsustainable in terms of both energy security and environmental concerns. He also said that it was essential to change these prospects and to set the planet on an energy-sustainable path. This statement is critical: the IEA projections are not a prediction, but a warning. The pursuit of current trends is encountering insurmountable constraints, creating a development deadlock, increasing inequalities between rich and poor countries and contributing to the social divide. Energy insecurity and the degradation of the local and global environment risk slowing down or even preventing economic and social development.

The desire for economic and social development is justified. But the IEA projections show that the pursuit of development according to the energy model of developed countries – which developing countries see as a goal to aim for – is quite simply impossible.

Four constraints of increasing magnitude are emerging:

- *economic constraints:* firstly in terms of investment to be made and secondly in terms of energy prices, especially oil, whose recent increases are already ruining the most fragile economies;
- *the limits of energy resources:* although the volume of hydrocarbon resources remains debatable, they are clearly finite and the 21st century will almost certainly see their decline and, consequently, a rise in prices. These resources cannot be relied on for sustainable development.
- *energy security:* energy independence is not a dogma, but excessive dependence weakens economies in terms of supply risks and increasing energy prices. Extreme dependence (the case of transportation and oil products) can lead to major conflicts[3].
- *damage to the natural environment, life and public health:* damage caused by energy production and consumption (dangerous emissions in the air and water, serious accidents, etc.) is considerable and has reached a global dimension that is mobilizing the international community (climate change).

A new energy model

Energy supply, which covers industrial activities ranging from the exploitation of primary resources to the delivery of energy products to final consumers, develops according to the extent and cost of the resource, investment capacities and the solvency of demand. This sector has its own dynamics, whether global or regional, for major commercial energies, and aims to meet the quantity and quality demanded by consumers.

Energy demand, on the other hand, is the result of economic and social growth that has its own dynamics linked to capacities for investment in public infrastructure and to the ability of companies, authorities and households to purchase goods and products. For households, as for many companies, energy demand results from investment and spending choices and possibilities often determined more by the cost of equipment (cars, housing etc.) than by energy prices, and thus largely detached from the energy question.

Energy supply and demand meet at the level of final energy consumption and hence of the price of the energy product consumed. For social or political reasons specific to each country, the price of final energy products is sometimes heavily taxed in relation to the production and supply cost (as with petrol in France), or sometimes, on the contrary, subsidized.

The traditional approach to the energy paradigm reduces the issue to one of energy supply, which must increase in order to meet – with the best supply and price conditions – growth in demand thought to be unlimited. Following the industrial revolution, energy became a major economic and strategic challenge. The regular increase in its production and consumption was the symbol and measurement of successful development in both capitalist countries and those with planned and centralized economies. The oil supply shocks of the 1970s made people aware that the reckless consumption of fossil fuels would result in them becoming more scarce and hence more expensive, and that the concentration of the most important resources in certain geographical areas is a factor of serious economic and political crises. They did not, however, affect the paradigm of prioritizing energy supply, resulting in the current deadlock.

This energy model could undoubtedly go on for a certain time if it remained confined to OECD countries. But the world includes two other areas of equal size (China and India), whose economic development is both legitimate and desirable. In the face of such demand, energy-intensive economic and social development is quite simply out of the question[d]: sustainable development is wholly incompatible with the current energy paradigm.

True demand: the energy service

Users (households, companies and local authorities) require not energy products themselves, but rather the goods and services essential to economic and social development, well-being and the standard of living[4], which can only be achieved if a certain amount of energy is consumed.

Obtaining a good or service requiring energy is the result of the combination of three terms, illustrated by the formula[5]: S = U*M*E.

- 'S' represents the energy service requirement;
- 'U' (for use) characterizes the way in which this service will be obtained, for example the means of transport for journeys, the kind of housing conditions and urban planning, the comfort levels sought, etc. This term is particularly dependent on the climate, but also on habits and lifestyles and, in a broader sense, on the 'type of civilization'.
- 'M' (for mechanism) represents the equipment or mechanism used to obtain the service required: taking the example of home comfort, the term M refers to the thermal characteristics of the housing and the type of heating used, domestic appliances, etc.;
- 'E' (for energy) refers to energy end-use corresponding to the service provided (S), with usage conditions (U) and the mechanism used (M): E is expressed in terms of the quantity of a specific energy product. The term E is the outcome of production, processing, transportation and distribution systems for energy products at final consumer level. The quantity of energy (E) needed can vary considerably for the same service (S) according to the conditions in which it is obtained.

There are numerous examples: the amount of fuel needed to obtain the same temperature inside a building, depending on whether it is well insulated or not; fuel consumption for a given journey depending on the means of transport; electricity consumption for the same light level depending on whether the light bulb used is incandescent or compact fluorescent, etc.

The new energy paradigm implies viewing the energy system as a whole including not only the energy sector (supply), but also energy consumption (demand) and guaranteeing its development so as to obtain S in optimal conditions in terms of resources, economic and social costs and local and global environmental protection. Energy policies must henceforth include a section on energy conservation, which entails drawing up and implementing measures and action plans concerning the terms U and M to obtain the service (S) while reducing the quantity of energy (E), in order to reach an optimum situation from an economic and environmental viewpoint.

Initiatives concerning term M have considerable technical content, as they first imply improving the energy efficiency of equipment. Researching and perfecting efficient equipment is therefore essential, but is only part of the process: this equipment must then be put on the market and brought into widespread use. A whole series of tools comes into play at this stage: legislation and regulations; information and communication; training; promotion and different kinds of financial incentives.

Initiatives concerning term U are more complex and longer term. They focus on 'behavior', whether that of consumers or of political leaders, at the national, regional or local level. More broadly speaking, they concern consumption structures, including their fundamental determining factors, such as travel requirements or the preferred type of housing. In the long term, urban planning and regional development are powerful tools for energy conservation. Globally speaking, energy conservation strategies encompass all human activities and sooner or later call into question the very characteristics of industrial civilization and consumerism.

Towards an energy conservation strategy

Following the rise in oil prices on the international market in 1973-1974 (the first oil shock) and 1979 (the second oil shock), OECD countries succeeded in safeguarding their economic growth by responding to these increases with the implementation of energy efficiency policies to which they devoted considerable sums. Over the following 15 years, per capita energy consumption in OECD countries was practically stable while gross domestic product (GDP) rose by 30% (although it had followed the same growth

Box 2

Where to save?

Savings can be made in all sectors:

▶ energy consumption for heating, cooling or ventilating buildings can be significantly reduced by certain designs[5] (or even rendered unnecessary in certain climates);

▶ a compact fluorescent light bulb uses up to five times less electricity than an incandescent one;

▶ initiatives concerning industrial processes usually lead to savings of 30 to 50%;

▶ using public transport rather than cars, or trains rather than trucks, consumes far less energy and generates less pollution.

over the previous 15 years). If the energy intensity of these countries had not progressed since 1973, their total energy consumption for 1987 would have been 1 200 Mtoe higher, or 130% of the annual production of OPEC countries at the time.

The rapid rise in prices therefore triggered action and investment aimed at improving energy efficiency. However this did not occur spontaneously, due only to market forces, but rather to the implementation of elaborate policies including economic, institutional and regulatory elements, with considerable State intervention:

- research and development programs concerning the improvement of industrial processes, construction techniques and materials, motors and electrical appliances, etc.;
- regulations on energy consumption, especially for buildings, but also in certain cases for automobiles and electrical appliances; energy efficiency labels; compulsory energy assessments for major energy consumers (industry, tertiary sector, transport);
- consumer information programs and training for technicians and managers;
- financial incentives (subsidies, soft loans, tax deductions) to stimulate innovation, demonstrations or investment for the rational use of energy;
- the creation of institutions, organizations and service companies for the design and implementation of programs and projects.

The European Commission's Green Paper on Energy Efficiency, published in 2005, calculated what the EU-25's primary energy consumption would be if energy intensity had remained at early 1970s levels. The contribution of energy savings thus made (compared to the kind of 'business as usual' scenario that could have been developed in the early 1970s), known as 'negajoules', is higher than that of the dominant energy, oil. Of course, not all of these energy savings are due to public energy efficiency policies: structural economic changes (a larger tertiary sector, higher overall productivity) and consumer adaptation to significant oil price increases also explain some of them. It is nevertheless very difficult to examine the individual influence of these different causes, given the high level of interaction between them: housing insulation standards introduced in most industrial countries over the last 30 years are clearly due to public policies, but they would perhaps never have been implemented if the oil shocks had not occurred.

Research carried out in different countries shows that over the next 20 to 30 years, vigorous energy demand management policies could lead to a 20 to 40% reduction (depending on the country) in the quantity of energy products needed to produce the services required, compared to the quantity needed if current trends are pursued. The European Commission estimates[6] the technical potential for final energy savings at 40%, half of which is considered to be economic[f]. The Green Paper on Energy Efficiency suggests that a 20% saving is possible by 2020 if measures already adopted and additional measures are applied to different sectors (Figure 1). Achieving the potential thus identified as maximal by 2020 would imply a shift in energy consumption between 2010 and 2015, with a return to 1990 levels by 2020. While this potential carries little weight in terms of global energy consumption, it indicates the scale of energy efficiency savings that could be achieved thanks to more efficient technologies, behavior and means of organization, which are themselves likely to spread across the world as a result of globalization.

FIG. 1 **Potential energy savings in the EU-25**

Potential savings in Mtoe	2020*	2020**
Buildings	56	105
Heating and air-conditioning	(41)	(70)
Electrical appliances	(15)	(35)
Industry	16	30
Transport	45	90
Cogeneration	40	60
Energy sector	33	75
TOTAL	**190**	**360**

* Rigorous application of measures already adopted. **Implementation of additional measures.
Source: European Commission, Green Paper on Energy Efficiency, June 2005

The prospect of sustainable energy demand

A number of global energy perspectives studies suggest a form of 'development through energy efficiency' that restores the balance to energy policies. They give high priority to controlling the evolution of energy demand, based on detailed analysis of development needs in terms of services requiring energy. The best known of these studies, published in 1987[7], showed that by applying the most efficient techniques available at the time to energy consumption, it would be possible to achieve a spectacular reduction in global energy consumption by 2020, without slowing down growth in Northern countries or hindering the development of Southern countries. It was demonstrated that the future of energy described in conventional forecasts was by no means inevitable.

Developed in 1990 by Benjamin Dessus and François Pharabod, the NEO scenario (new energy options) is part of the same approach[8], but predicts a slower shift in energy behavior and has a longer timescale of 2100 (at which time demographers predict a stabilization of the world's population at around 11 billion people). This scenario also imposes two environmental standards: reducing nuclear energy until it is completely abandoned in 2060 and limiting carbon emissions to 3 billion tonnes by the same date[g]. In terms of global risks, only such energy efficient scenarios seem capable of avoiding irreversible changes. Their main advantage is that they provide sufficient room for maneuver to allow time to plan and prepare sustainable energy systems. From the economic viewpoint, these energy efficient scenarios compare favorably with energy abundance scenarios: the costs of energy production and distribution are in fact frequently higher than those of energy efficiency measures and initiatives. These scenarios capitalize on this advantage.

International research carried out in the 1990s produced a synthesis of the different visions of the possible future of energy by 2050 and 2100. Likewise, research published in 1998 by the IIASA and used since then by the World Energy Council, along with the World Energy Assessment (WEA) produced under the aegis of the United Nations, describe three families of scenarios that respond to the world's energy requirements by these dates, while following very different paths in terms of both energy consumption and production.

From a level of nine Gtoe in 1990, primary energy consumption reaches 14, 20 and 25 Gtoe in 2050 and 21, 35 and 45 Gtoe in 2100 respectively in the low (or environmentally-friendly), medium and high scenarios. These considerable differences reflect the fact that decisions made today on the directions energy policies take are fraught with consequences for the next century.

A recent study[9] presents two energy scenarios for France towards 2050: a 'business as usual' (BAU) scenario comparable with that of the IEA and a 'Factor 4' (F4) scenario aiming to reduce France's CO_2 emissions by 75% at the end of the period compared with 1990 levels. In addition to the French situation, this study also examines European and global energy systems. It arrives at a final energy consumption level for 2050 of around 16 Gtoe in the BAU scenario[h].

The F4 scenario, however, arrives at a final consumption level for 2050 that is slightly lower than the initial 2001 level: after stabilizing between 2015 and 2020, global energy demand would subsequently decrease. Such a result could only be achieved if all countries were to implement a vigorous energy conservation policy across all sectors. This is the sine qua non condition for the reduction in greenhouse gas emissions essential to the mitigation of climate change.

Energy efficiency: a universal strategy

Business as usual energy scenarios clearly highlight the political deadlock, economic failure and environmental insecurity that would result from the pursuit of current energy consumption trends at the global level. Other scenarios, based on 30 years experience in industrialized Western countries (unequal experience, fluctuating policies, limited efforts) and on detailed technico-economic studies show, on the other hand, that the reorientation and reduction of global energy consumption are possible and that constraints can be transformed into motors for sustainable development.

A global energy conservation strategy is needed on a large scale in order to respond to constraints concerning energy security and the mitigation of climate change. Such a strategy is not only the principal tool for reducing energy vulnerability and controlling greenhouse gas emissions, but is also a factor of economic development in terms of reducing energy spending and creating new activity and employment. It is a key requirement for economic and energy policies. This urgent strategy is possible: there is considerable potential for energy conservation – which implies behavioral changes but also the widespread adoption of the most efficient techniques – in all sectors of activity, all countries and all regions. The issue of infrastructure, through urban planning and regional development, is critical.

If they apply such a strategy, industrialized countries – with those that waste the most energy resources at the forefront – can significantly reduce their energy consumption. Developing countries need to increase their own energy consumption, but they can do this with growth rates far lower than those observed in industrialized countries in the past, with the well-known damage they entail. For most countries, including major energy producers, energy conservation is the principal energy resource for the decades to come.

Energy efficiency is a doubly advantageous strategy: 1) for the same service rendered, energy that is neither consumed nor produced is energy that goes the furthest to reducing pollution and risks of all kinds linked to the energy system. Furthermore, most energy efficiency improvement initiatives are the least expensive for environmental improvement: these initiatives are cost-effective due to savings on the energy bill; 2) the financial resources saved for energy supply can be devoted to other needs, thus improving the content of economic growth: building housing and health and educational facilities, developing public transport, etc. This economic factor is particularly sensitive at times when energy prices are rising, especially oil prices, for both States (commercial balance) and consumers.

Achieving this potential implies mobilizing human and financial means that meet the challenges (these means create value). Priority must be given to increasing human and institutional capacities (agencies, local teams, expertise, networks) in all countries: it must become a key concern for international cooperation. Furthermore, specific financial means and mechanisms must be set up: public funds, guarantee funds, public-private investment funds and developing energy services companies.

Energy conservation is top of the agenda for policies that must be set up rapidly, as it has the greatest potential, can be applied to all sectors and all countries, is the best tool for mitigating climate change, helps slow down the depletion of fossil fuels and guarantees that a growing share of energy consumption will be assured by renewable energies.

This challenge can only be met if construction begins on a new paradigm; an energy systems model that is compatible with sustainable development, in order to meet "the needs of the present without compromising the ability of future generations to meet their own needs"[10].

[a] The economic and energy figures used in this document are from the Enerdata database.

[b] Energy consumption in buildings: heating and, to a lesser extent, air-conditioning, cooking, hot water, domestic appliances, office equipment, etc.

[c] The progress of electricity reflects a sector where energy output, from power plants to distribution losses, is less efficient.

[d] Imagining simply that the OECD's situation is frozen and that China and India, with the same population, arrive at the same level of per capita energy consumption as the OECD, these two countries alone would create a 'need' of 16.7 Gtoe of primary energy, compared to 7.7 Gtoe today (out of 11.1 Gtoe in the world).

[e] The * symbol represents the combination of the three terms, with no special mathematical sense.

[f] The 'profitable' share of technical potential, i.e. where the cost of savings is lower than the cost of the energy saved. This share clearly grows as energy prices rise.

[g] The NEO scenario is, to the author's knowledge, the first global scenario to impose standards in this way.

[h] If the same ratio between final and primary energy as in 2004 is applied, this corresponds to a primary consumption of 21 Gtoe, close to other scenarios such as the WEA medium scenario.

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Once experts declared that coal would disappear from the global energy balance, but it is now doing more than simply holding its position: its growth is continuing and progress in the coal industry along with abundant reserves may enable coal to dethrone oil as the world's leading source of energy in the decades to come. In addition to the development of alternative energies, it is therefore vitally important to encourage the rapid emergence of the cleanest coal technologies, from combustion to CO_2 storage, in order to preserve the climate.

Challenges and constraints for energy supply: The coal hard facts

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Coal was the leading energy source of the 19th century, but is it set to regain this position in the 21st century? Many observers believe so. However, 25 years ago experts were announcing the rapid decline of coal in global energy supply, and this appeared to be well underway in Europe. How is it possible that such contrasting visions have followed one another in such a short space of time? Since scientific and technological upheaval is not the cause, the explanation must be sought in a series of changes whose convergence has not been fully appreciated, and must therefore be reassessed.

The result is a definite increase in environmental risks, including climate change, which could nevertheless be mitigated by the development and dissemination of new technologies for converting solid fuel into gas and/or electricity and carbon dioxide sequestration. But these 'clean coal technologies' will only be adopted if they are driven by R&D (Research & Development) policies and drawn by energy policies aimed at preventing the consequences of the greenhouse effect: what do we know about these policies in the major regions of the world and what can we expect in terms of sustainable development?

The reasons for the return to the forefront

"The future is clean coal," ran the headline of *The Economist* in 2004, in the wake of several reports announcing the return of solid fuels to the forefront[1]. This was barely 25 years after their imminent departure from the global energy balance was announced: in 1979, IIASA researchers observed the way different energy sources were substituted over a very long period of time and concluded that there were such striking regularities that the energy system seemed to have a plan, a clock and a will of its own. The future prolongation of its past performance would lead to coal being placed permanently out of play, pushed out of the system by competition from natural gas, nuclear fission, solar power or fusion, well before 2050[2].

Although it has progressively disappeared from the energy landscape in certain European countries, such as France, coal has consistently come second in the global energy balance, standing at 24% in 2004, behind oil (36%) but ahead of natural gas (21%). But is this high score – which reflects the fact that world coal production doubled between the first oil shock (1 952 Mt) and 2004 (4 600 Mt) – set to last? Most recent global forecasts believe not, predicting that coal will be outstripped between 2010 and 2020 by natural gas, extolled for its abundance, affordability, low levels of pollutants and CO_2 and the fact that it can be turned into electricity in a very efficient manner thanks to combined cycle turbines (*World Energy Outlook*, 2004).But this perspective is currently shifting for the 2010-2020 scenario, and even more so for the 2050 scenario.

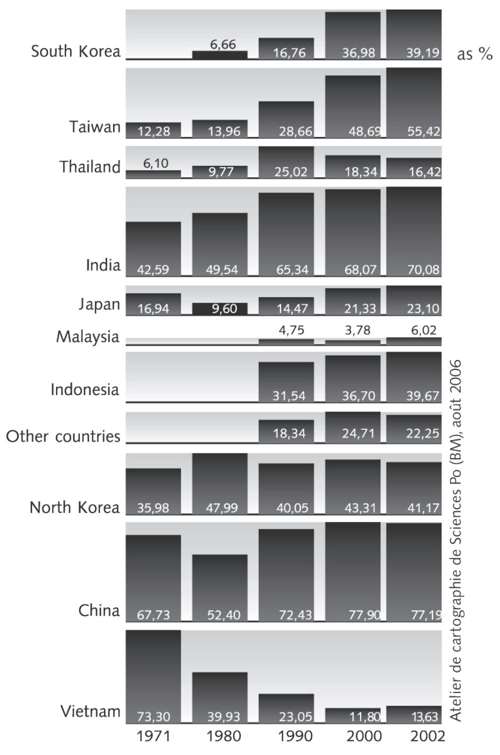
Coal heads long-term perspectives

The latest IEA forward-looking exercises for 2030 are unequivocal: the gap between gas (24.2%) and coal (22.9%) gets smaller in the reference scenario and disappears in the deferred investment scenario, where tension surrounding the supply of hydrocarbons drives up gas prices (World Energy Outlook, 2005). The United States government has predicted that coal consumption will overtake gas consumption as early as 2010 and will exceed it by 20% in 2030, when only expensive liquefied natural gas (LNG) will be able to restore market balance[3]. This contrast becomes more pronounced in the long term: the theory of peak oil towards 2030 then peak gas between 2040 and 2060 inexorably plays in favor of solid fuels. Failing real political determination to avert the risks of climate change[a], world coal consumption could double between 2004 and 2050[4], with coal and oil finding themselves neck and neck in less than 50 years.

At the root of this turnaround are a number of technological, economic and geopolitical changes. The principal change concerns the surge in demand for electricity, which cannot be met without fossil fuels. Solid fuels are not only used to feed thermoelectric power stations. In 2005, 65% of world coal consumption was put to this use, with the rest shared between residential heating (3%), industrial heat generation (17%) and iron ore reduction for the iron and steel industry (15%). In Russia, China, India and many Asian countries, these non-electric uses reach higher proportions, standing at between 40 and 50%. Conversely, they do not exceed 15% of coal consumption in the United States and the other OECD member countries.

The increasing concentration of coal uses in the electricity sector is universal, but its rapidity depends on the pace of urbanization and access to cleaner and more flexible energy sources. Improvements in gas supply in countries such as China and India will almost certainly reduce coal consumption in households and light industry: the growth of thermoelectric power plants is then expected to draw 90% of additional demand for coal in the long term. The only conceivable new large-scale use for coal in the future is its conversion into synthesis fuels (coal-to-liquids), which could absorb up to 1 Gt of solid fuels in the world by 2050[5].

Fig. 1 **Coal-fired power generation in Asia**



Source: IEA, 2002. Hong Kong is included in China.

Backcasting scenarios (developed retrospectively based on a vision of electricity consumption in 2050) illustrate the potential results of ambitious energy conservation policies. They limit world electricity production in 2050 to 32 000 TWh[6], in other words an increase of around 80% compared to today's level. Unfortunately they demand the fulfillment of conditions so far from reality that it is necessary to retain the hypothesis of annual electricity demand growth of at least 2.8%, principally driven by underdeveloped African and Asian countries and certain emerging countries (including China, India and Brazil). In response, electricity supply could increase from 17 448 TWh in 2004 to around 60 000 TWh in 2050[7]. All production chains will contribute to this, but those that convert so-called primary sources (hydraulic, nuclear, renewable) will play a smaller part than hoped.

Social objections, later consolidated by the Three Miles Island and Chernobyl disasters, undermined the initial expansion of nuclear energy and have capped its contribution to world gross electricity production at 16% since 2002. In IEA projections, nuclear energy stagnates below 3 000 TWh until 2030, since the installation of new capacities in Russia, China, India and Japan fails to offset cutbacks in North America and Western Europe. While the prospect of a considerable surge in hydrocarbon prices and increasing fear of disastrous climate change may shift trends, the inertia of the power generation sector is such that the return of nuclear power can only be a slow one, bringing its maximum share in electricity production to 25% by 2050.

Renewable sources are unlikely to fare better, since the very moderate growth of large hydro will not be offset by the far more rapid growth of other renewable sources (biomass, small hydro, wind, solar and geothermal power). Despite abundant resources in many parts of the world, most are in fact sporadic, uncertain and difficult to store[8]. Although relatively well suited to scattered production and fragmented electricity use, they are far less so when it comes to feeding large networks with electricity on a scale such as that required by the electrometallurgical industry or major cities, such as Shanghai. In the aforementioned reference scenarios, their contribution does not exceed 20% by 2050.

Coal, the most abundant of fossil fuels

Over the next few decades, 55 to 60% of world electricity production will therefore undoubtedly still require the conversion of fossil fuels, with coal taking first place, especially in Asian countries, which are poorly provided with hydrocarbons (Figure 1)[9].

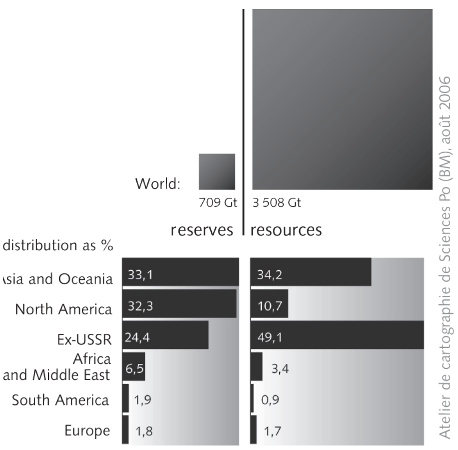
In North America, despite strict environmental regulations, coal is used for 20% of electricity production in Canada and 52% in the United States. This is due to the fact that the price of coal compares favorably to that of natural gas since, faced with stable prices for steam coal in current dollars, gas prices almost quadrupled between 1960 and 2004 – to such an extent that the stricter environmental standards expected have little chance of halting the current progress of coal-fired power in the United States. In Western Europe, competitive margins are tighter but already favorable to coal, except when compared to nuclear power, for both baseload and mid-peak[b]. Under January 2006 conditions[c], the MWh produced by a pulverized coal plant costs 30% less at baseload than that produced by a combined cycle gas plant. The costs are equal mid-peak including a CO_2 value of 20 $/t. The power industry believes that due to the increase in gas prices (indexed to oil), coal will remain competitive in the long term. Even if CO_2 emission quotas are reduced, a further increase in gas prices could neutralize the advantage it holds in terms of its lower output of greenhouse gas emissions.

The current increase in competitiveness for steam coal will last if the expected growth in demand for coal does not alter the long-term trend of its CIF prices (which, in current dollars, only temporarily left the 40-60 $/tonne range, faced with much higher and far more fluctuating equivalent oil and gas prices). Certain sources do not hesitate to forecast a ratio of 1 to 3-4 in favor of coal by 2030, since the dynamics that succeeded in the past can only be amplified by the abundance of coal resources (as opposed to petrol and gas resources) and by the coal industry's ability to efficiently combat the risks of declining output[10].

Despite their differences, assessments of resources agree at least on one point: around 70% of the non-renewable sources still available exist in the form of solid fuels. These resources include considerable proved recoverable reserves, even when retaining an estimate of 709 Gt (Figure 2)[11] rather than the excessive figure of 900 Gt proposed by the IEA[12]. They are shared fairly equally between Australasia (principally China and Australia), North America and the former USSR.

The estimation of resources is even more debatable than that of reserves. From more than 6 000 Gt a few years ago (World Energy Assessment, 2000), they were reduced to 3 500 in 2004, but could soon go up again. For the time being, the abundant resources in Eastern Siberia are attracting the most interest. It can be assumed that the coal industry will be able to exploit such resources without escalating costs. In most of the world's major coal-producing regions, steam coal is mined at less than 30 $/tonne, allowing – after transport – power plant delivered prices of 40 to 60 $. Faced with inevitable declining output in the oldest mining regions, the industry will be able to continue to transfer extraction for a certain time towards open-cast or shallow reserves (United States, Australia and Russia) in basins where ex-mine costs are around 10 $/tonne. It will also concentrate on the expansion of rail and port infrastructure, as the Australians and South Africans are doing.

Fig. 2 **Coal proved recoverable reserves**



Source: BRG, 2004. Hard coal only.

Important technological progress

Although it helps ensure a timely increase in electricity supply at a controlled price, the massive return of coal to the global energy balance is also fraught with dangers: escalating mining morbidity and mortality; increasing environmental damage caused by the expansion of underground and open-cast mines; and an upsurge in the volume of pollutant emissions (SO_2, NO_x, mercury, residual ash, radon) whose harmful effects on public health are well known. The acidification of lakes and forests no longer seems as worrying as 20 years ago, thanks to progress in desulfurization and denitrification in industrialized countries, but mercury pollution, which knows no boundaries, has taken over[13]. The major danger is the increase in greenhouse gas emissions: trajectories associated with coal reference scenarios end with emissions more than doubling by 2050, whereas they must be halved if this threat is to be mitigated. These risks must be reduced by means of important technological changes.

Improving combustion and reducing emissions

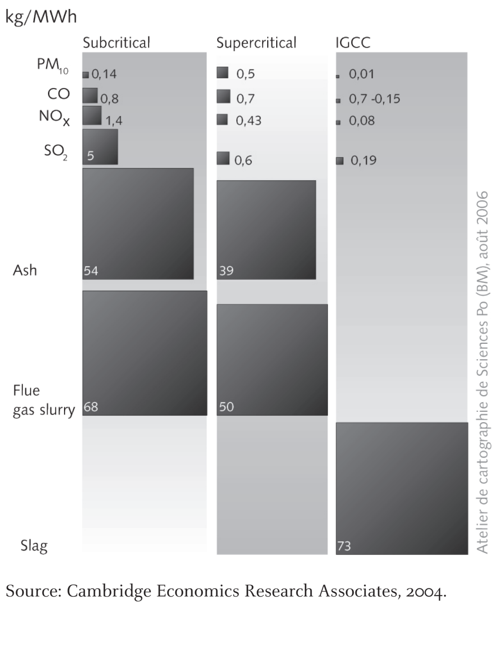
In the wake of the first United States Clean Air Act (1970), followed by the series of international agreements inspired by the Geneva Convention of 1979, the OECD member countries have made considerable progress in reducing pollution from pulverized coal-fired power plants. Innovations have made it possible to reach standard denitrification rates of around

50 to 70% and even 70 to 90% (selective catalytic denitrification)[14].

This equipment has led to a five-fold reduction in SO_2 emissions in France and a two-and-a-half-fold reduction in NO_x emissions, which is only one stage, as emissions ceilings are to be lowered once more by national regulations, spurred on by the European directive on large combustion plants (LCP). The permissible limits for emissions of very fine particles; heavy metals (lead, cadmium and especially mercury), ash, bottom ash and aquatic waste are also expected to be tightened by 2015, the deadline anticipated by electricity companies in their R&D programs. It is therefore to be expected that coal combustion will become cleaner and cleaner in OECD member countries, although new mechanisms spread at varying rates from one country to another. China, which is increasingly aware of the social cost of the pollution generated by its coal-fired power plants, is fitting its new installations with such equipment, but 95% of its existing facilities still lacked desulfurization systems in 2003, and will prove difficult to equip[15].

The most significant reductions in pollution and greenhouse gases may come from advanced combustion techniques (Figure 3), which improve conversion efficiency[16]. Already high in the most recent subcritical pulverized coal-fired power plants (45% on NCV), this efficiency increases further with the move to supercritical and, in the future, to ultra-supercritical plants. They are also associated with other possibilities for reducing emissions of all kinds in the case of fluidized beds and especially the integrated coal gasification combined cycle process, or IGCC (Box 1).

Fig. 3 **A comparison of pollutants from three kinds of power plants**



Source: Cambridge Economics Research Associates, 2004.

Carbon dioxide sequestration

A 25% increase in the efficiency of existing and future installations, brought about by the aforementioned techniques being put into widespread use, would only succeed in reducing the growth of CO_2 emissions by 50%. More radical technological changes therefore remain necessary, including carbon dioxide sequestration. Problems must be resolved in each of the three links of the chain: capture, transportation and storage[17].

Of the three main kinds of techniques for separating CO_2 from other gases (oxygen, steam, nitrogen) and capturing it, post-combustion by chemical absorption is the most tried and tested, but is less efficient (between 30 and 60% losses in a coal-fired plant) than pre-combustion and especially oxy-combustion, which are still at the experimental stage. In all cases, the gas captured is dehydrated and compressed before transportation. In the current state of technology, the entire chain before storage requires additional energy consumption estimated at 10 to 40%, depending on the procedure chosen.

Transporting CO_2 maintained in its supercritical state by onshore or offshore gas pipelines is common practice for oil companies (for advanced oil recovery by CO_2 injection). Over long distances at sea, the CO_2 may be transported in a liquid state, under moderate pressure and at low temperature, in ships such as gas tankers.

This leaves storage. Holding enormous quantities of gas for hundreds of years (at baseload, a 1 000 MWe plant produces around 6 Mt of carbon dioxide per year) is only possible in high capacity reservoirs that are watertight and deep enough (below 800 meters) for the pressure to maintain the gas in a liquid state. The idea of storing gas in the ocean has been abandoned on the grounds that it is too dangerous for marine flora and fauna, leaving three options : natural reservoirs emptied of the hydrocarbons they contained, for which injection techniques are fully understood, but which do not exist in all parts of the world; deep saline aquifers, which are sufficiently watertight and are better distributed throughout the world; and unmined coal seams, which can be used thanks to their capacity for trapping gas, especially if the CO_2 injected replaces the methane extracted.

Could CO_2 sequestration be developed to deal with the scale of emissions produced when electricity is generated using fossil fuels, which could reach 870 Gt of cumulated CO_2 by 2050? The answer depends first and foremost on storage capacities and their distribution throughout the world. The best known are those established in former hydrocarbon deposits. Their global capacity is estimated at 560 to 1 170 Gt of CO_2, but their relatively unequal distribution does not fully cover the regions that produce the most emissions. These regions must therefore rely on storage in deep aquifers, which could hold as much as 10 000 Gt, or on coal seams, which are far smaller, but both of these possibilities are as yet little understood. Part of their emissions would undoubtedly escape capture[18].

In addition to the insufficiency of storage capacities, the extra cost of power generated by a decarbonized industry could also limit sequestration. Although estimates of the costs of these solutions remain tenuous, based on current average kWh costs, sequestration would represent an additional cost of around +60% for gas-fired plants and +90% for coal-fired plants. The different R&D programs underway aim at halving the average cost per tonne of CO_2 avoided, in other words, an extra cost of around +50% by 2020 for coal-fired plants, which does not seem unacceptable in view of the uncertainties weighing on future fuel prices[19].

Box 1 Advanced coal combustion techniques

Supercritical and ultra-supercritical plants:

Thermal power plants installed in 2005 are normally characterized by a supercritical cycle reaching an efficiency level of 46% for hard coal and 43% for brown coal. New progress in fluid mechanics, thermodynamics and materials make it possible to aim for 51% in 2010 and around 58% later. The technical feasibility and economic value of this new phase, known as ultra-supercritical, nevertheless remain to be proven.

Fluidized beds:

At the same time as the development of supercriticals, progress is also underway concerning fluidized beds. Circulating fluidized bed combustion (CFBC) – which is marginal in comparison with the previous technique – uses the recirculation of solids to ensure more thorough combustion despite a relatively low temperature in the combustor. It has several advantages: it increases the value of mediocre quality fuel, destroys certain pollutants at the source, is easy to use and can be adapted to rapid load variation.

In relation to pulverized coal (PC) technologies with flue gas treatment, CFBC is nevertheless disadvantaged, especially by lower efficiency (39 to 40%) and small plant sizes (from 50 to 300 MWe). Research underway aims at a size of 600 MWe and efficiency levels of 45% on NCV with the move to supercriticals and a kWh cost equivalent to that of a PC plant without flue gas treatment. Furthermore, research is ongoing concerning pressurized fluidized beds; which would make it possible to achieve greater efficiency.

Integrated gasification combined cycle:

In the longer term (2010 to 2015), the Integrated Gasification Combined Cycle (IGCC) seems to be, according to most experts, the 'clean coal' technology of the future. It consists in feeding a combined cycle (combustion turbine + steam turbine) with a gas produced from the partial pressurized oxidization of different fuels. It has numerous advantages: excellent efficiency (45%, perhaps even 50% in the future); much cleaner coal to electricity conversion; lower water consumption; high flexibility in terms of both input (coal, asphalt, petroleum coke, biomass) and output (electricity, heat, synthesis gas); and is easy to adapt to CO_2 sequestration.

However, these numerous advantages are still not enough to dethrone supercritical pulverized coal-fired power plants. Above all, reliability and costs must be improved. Different technical progress in this field is already underway.

Cleaner fuels

In addition to the development of combustion techniques that generate less pollution and CO_2 thanks to greater efficiency, research is also continuing on burning cleaner coal or extracting the energy contained in coal seams in gas form. The different techniques explored include cleaning the coal mined, using mixtures of coal and water, capturing methane in mines and *in situ* coal gasification (Box 2, next page).

The strategies and policies of major stakeholders

Progress in coal technologies will reach its potential if, in the eyes of electricity companies, it seems more reliable and less risky than the conversion of natural gas, fissile materials or renewable sources. The continuing hostility of a sector of public opinion towards nuclear power and the prospect of diminishing hydrocarbon resources are favorable to this change, especially in countries where natural gas remains expensive (China, India, Japan) or is becoming so (United States). However, these negative factors are not enough.

The institutional environment of firms influences the development and circulation of clean coal technologies in different ways. Public coal R&D policies and energy supply security policies clearly play in their favor, but the effects of environmental protection policies are more ambiguous. By increasing the price of coal, they reduce its use; by penalizing the least efficient techniques, they encourage their replacement by new techniques. But which ones? Will power plant renewal in OECD member countries – which will culminate around 2020 – be limited to ultra-supercritical plants, or will it take the leap into IGCCs and systematic CO_2 sequestration? What would be the result of a technological bifurcation of this kind on China and the other Asian countries that will follow 20 years later?

The United States and Canada

Praise where praise is due. Of all countries, the United States is the only one that meets three conditions that are highly favorable to the development of clean coal technologies: 1) it needs coal to satisfy its energy needs without overly increasing its level of external dependency; 2) the prospect of increasingly restrictive environmental standards; 3) an unequalled technological and financial might.

Long before he signed the US Energy Policy Act (which Congress had debated for several years) in August 2005, President George W. Bush had launched the Clean Coal Power Initiative (CCPI). Granted two billion dollars in federal funding over 10 years, this program aims to reduce or even eliminate pollution (especially mercury) and CO_2 emissions, to double coal conversion efficiency and to improve energy security. The first of these three goals responded to the Clean Skies Initiative, aiming to reduce SO_2, NO_x and mercury emissions by 70% by 2018. This program includes the emblematic FutureGen project, presented as the "world's first zero-emission coal-fired power station"[21]. Launched in 2003, this project represents 275 MW and a cost of one billion dollars and is intended to demonstrate the feasibility of an IGCC plant using coal to produce electricity and hydrogen without emitting either pollutants or CO_2, as this gas would be captured and stored. Operations are expected to begin in 2012, and the extra cost of electricity generated at this time should not exceed 10% in comparison with electricity produced in 2005 by conventional plants. The CCPI has inspired and consolidated industrial initiatives such as the electricity producers who mobilized around CoalFleet for Tomorrow or CoalFleet, under the leadership of the Electric Power Research Institute (EPRI). This program focuses on the development, demonstration and circulation of all kinds of clean power stations (some 50 designs). In 2005 this large-scale learning-by-doing process mobilized companies that owned more than half of the United States' thermoelectric capacities[22].

The Canadians are also active in this field. At the Energy Technology Centre (CANMET), coal R&D focuses principally on oxy-combustion as a means of eliminating the stage of capturing CO_2 before storing it, as well as on fluidized beds. Furthermore, the Canadian Clean Power Coalition (CCPC), which includes seven companies representing over 90% of Canadian electricity production, plans to use one billion Canadian dollars of investment to demonstrate the removal of CO_2 produced by an existing power plant by 2007, then to adapt the mechanism developed to a new plant by 2010[23].

Major Asian and Australasian countries

Deprived of a coal industry since the closure of its last mines, Japan remains the world's largest importer of coking and steam coal. Concerned about the quality of its environment, it has only installed large-scale supercritical steam cycles (600-1 000 MW) with intensive flue gas cleaning since the 1960s. For the future, the country is counting on IGCCs. The Clean Power R&D Co., created by electricity companies, is in charge of developing the necessary technology and building a prototype with the participation of Mitsubishi. Furthermore, a pilot project was launched in 1998, capable of gasifying 150 tonnes of coal per day, integrated into an installation with fuel cells aimed at converting chemical energy from hydrogen into electricity[24].

In the 1960s, Chinese engineers began to develop their own small fluidized bed models (CFB), and 2 000 units have been installed over the last 15 years, with 300 under construction in 2004. These relatively small installations (less than 300 MW) nevertheless represent only a very minor part of Chinese electricity production, which is still mostly made up of pulverized coal plants, whose average efficiency does not exceed 30%. The construction of this sub-critical equipment is increasingly giving way to large-scale supercritical cycles, which are becoming the norm. This tendency towards substitution helps to improve air quality[25]. China is also working in several different directions, usually in partnership with major foreign manufacturers: ultra-supercriticals, circulating fluidized beds of over 100 MW, IGCCs with a demonstration project, coal polygeneration and gasification, CO_2 sequestration (with the support of the European Union), methane extraction from coal mines and transportation via coal pipelines.

Box 2

Advanced techniques in coal mining

Cleaning:

In Western Europe and North America, coal is screened and washed before leaving the pit top in order to reduce the volume transported and to make it easier to use. Over the next few decades, the contribution of coal cleaning to the quality of the environment will depend less on progress in methods than on simply implementing washing techniques in all mines that do not yet use them, especially in China, where 75% of coal mined is still not cleaned, partly due to a lack of water in the regions that have become the major producers. Elsewhere, gasification will almost certainly be chosen over intensive cleaning.

Coal-water mixtures (slurry):

These mixtures were developed over the last 25 years with a view to extending the range of uses for coal, enhancing the value of wet cleaning residue and making it easier to transport solid fuels (coal pipelines). Although this technology is not new, progress is still expected in terms of increasing distances (aiming at 1 000 km or more), in the form of powder, sludge or logs. Projects are being studied in China, Russia, Canada and between China and Japan[20].

Capturing methane in coal mines:

Coal mines contain large quantities of methane, which is held in coal pores. Dangerous for miners (firedamp explosions) and the environment (natural release of greenhouse gases), this methane can also be exploited, as is the case in the United States, where it represents 7% of national production of natural gas. It is collected either by drilling in unmineable coal seams, by capturing gas before the face in active mines, or by collecting the gas remaining in disused mines. Developed in the United States, this practice has spread to Canada, Australia and especially China, where it is hoped that by 2015 the equivalent of 12.5% of national consumption of natural gas will be extracted in this way.

Underground coal gasification:

If carried out on a large scale, this technique would resolve a number of difficulties, especially environmental ones. The technology involved is apparently simple, since it involves using a probe to inject a gasification agent (water, steam, air and/or oxygen) into coal seams in order to transform it into a combustible gas formed principally of CO, H_2 and CH_4. The gas recovered can be used either directly as a fuel to drive a turbine, or as a synthesis gas to make fuel oils or chemical products.

Despite being tried many times in the past and revived in the wake of the first oil shock, leading to new technical progress, production using this technique cannot yet compete with natural gas, but new progress could change this situation.

In India, the scarcity of natural gas resources encourages technological changes making it possible to enhance the value of mediocre-quality coal. Hence investment by the Oil and Natural gas Commission (ONGC) to exploit coal-bed methane and make progress in terms of *in situ* gasification. As the world's largest coal exporter, Australia clearly has every interest in ensuring that coal mining and combustion are not synonymous with environmental damage. In March 2003, the Australian Coal Association therefore mobilized industrial operators, universities and governmental authorities within Coal21, which aims to encourage the progress of the near zero emission power plant (NZEPP) along with hydrogen production. After a broad consultation organized in 2003, a national action plan was published in March 2004.

All these countries, joined by South Korea, replied positively to the United States' appeal to create the Asia Pacific Partnership on Clean Development and Climate in July 2005. Sometimes presented as a war machine against the Kyoto Protocol by two countries that refused to ratify it (United States and Australia), this partnership may also contribute to a broader distribution of new coal technologies.

Europe

What role will Europe play in the development of clean coal technologies? The rejection of nuclear power by some of its members, the well known limits of renewable energy and the prospect of rising natural gas prices ought to lead Europe to take a new look at the role of coal in its energy supply. Additionally, stricter environmental standards in Europe and its leading position in the application of the Kyoto Protocol, with the opening in 2005 of a carbon market, are incentives for the distribution of clean combustion techniques. The European countries that are the most concerned (with Germany at the forefront) and the European Union seem determined to take up the challenge.

Where coal combustion is concerned, ultra-supercritical steam cycles have the wind in their sails. The Fifth Framework Programme for Research and Development (FPRD) has financed research aimed at bringing the efficiency of plants up to 55%, thereby reducing CO_2 emissions by almost 15%. But combined cycles – possibly with cogeneration – fed by solid fuel gasifiers, are also being examined: the Cleaner and more Efficient Gas Turbine (CAMEGT) is striving to coordinate R&D with the principal gas turbine manufacturers and different public research centers. However, with the arrival of the 6^{th} FPRD, European R&D has turned its attention to the field of CO_2 sequestration, with the firm intention of gathering the critical mass in terms of integrated projects and networks of excellence. One of the first programs launched is the CO_2 from Capture to Storage project (CASTOR), piloted by the IFP. It aims to make it possible to capture and geologically store 10% of European emissions or 30% of those from major installations, principally power plants. Its first achievement, the Esbjerg plant (Denmark), was inaugurated in March 2006.

The movement is expected to increase pace with the launch of the 7th FPRD in April 2005, which provides a link between sequestration, clean combustion in power generation and hydrogen fuel cells. Undoubtedly influenced by new oil trends and United States projects, European R&D is changing perspective: fossil fuels will play a major role in electricity production; environmental accounting of this supply imperatively requires a reduction in CO_2 emissions; and European industry must remain highly competitive in this field.

An inescapable challenge

The rise of coal in the global energy balance therefore seems inevitable, and this is not good news. Faced with such a dilemma, no solution can be overlooked: the rapid circulation of very low-emission energy use techniques, the widespread use of non-coal sources (nuclear and renewable), and the sequestration of carbon produced by all kinds of combustion, including coal. The role played by the latter solution in the required reduction in CO_2 emissions by 2050 will depend on certain changes, especially geological storage capacities and the technological choices of electricity industries.

On a global scale, depleted oil and gas reservoirs alone would provide sufficient capacities for absorbing the 460 Gt expected to be emitted by fossil fuel power generation between 2020 and 2050. By this time it should be possible to capture 66% of emissions and thus limit the growth of CO_2 to 16% between 2000 and 2050[26]. It is thought that research programs underway will soon shed light on the issue of the geographical distribution of reservoirs.

Uncertainty relating to the technological choices of electricity industries is infinitely greater. For most of those that use coal thermal power for all or part of their production, the reference technology is now the supercritical cycle, for which the average unit efficiency of 45% is expected to continue rising. In response to the rapid expansion of its electricity production capacities, China has used it as the basis of the standardized construction of its power plants and a considerable reduction in their costs. This strategy – which can be applied to all emerging countries – may create a technological barrier excluding IGCCs, a more promising technology (especially from the viewpoint of carbon sequestration).

The technological competition underway is even more uncertain given the fact that the challenges involved are as much geopolitical as economic. In the United States and Japan, IGCCs are backed by major manufacturers, but also by the authorities, who wish to prevent China from taking the lead in terms of electromechanical construction. Will their efforts to rapidly improve the reliability and competitiveness of IGCCs bear fruit before the great wave of power plant renewal begins in OECD countries around 2020? If so, will the learning effects be enough to ensure that the IGCC/CO_2 sequestration combination moves far enough ahead of the supercritical/ultra-supercritical cycle and establishes itself in emerging countries, whose power plants will be up for renewal around 2040? These questions reflect the importance of a potential technological bifurcation, but also the impossibility of closing the matter.

The resulting uncertainty is no excuse for opposition to change, especially in Europe, where several countries are beginning to realize that they were rather too quick to sacrifice their fund of skills accumulated since the 19th century. The turnaround observed is encouraging, providing that R&D focuses on the most promising technological innovations in terms of reconciling the return of coal with the demands of sustainable development.

a This scenario – in which coal is doubled – represents an increase from 11.2 to 22.3 Gtoe of primary energy between 2004 and 2050, meaning an increase in CO2 emissions from 7.1 to 12.1 Gtce.

b Baseload corresponds to a steady flow of power at all times throughout the year, and mid-peak to power produced according to periods of high demand.

c Coal imported at 53 $/tonne and gas at 6 $/Mbtu.

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The energy model on which the industrialized world is built cannot be generalized without risk to developing countries. In view of limited resources and environmental challenges, the very rapid growth of emerging countries raises a major problem in terms of energy strategy. Rather than follow the dangerous path of development based on fossil fuels, these countries could preserve their growth by opening the way to a new energy paradigm.

Satisfying energy growth in emerging countries

ECL engineer, doctor of energy economics co-founder and president of Enerdata SAS.

Bertrand Chateau

Today assessments made are alarming: given the unprecedented requirements of the major emerging countries, the generalization of the OECD energy model no longer appears to be reconcilable with sustainable development. Analyzing the reasons for this incompatibility raises questions about the link between socio-economic development and growing energy requirements: from this point of view, is the historical OECD model universal, or does it reflect specific historical circumstances?

In terms of energy strategy, the paradigm that has been dominating the world for over a century is based on the industrial past of Europe and the United States. If it is truly impossible to extend it to the rest of the planet from the viewpoint of sustainable development, do credible alternatives exist? Forecasts highlight the need to rethink the satisfaction of the growing energy requirements of emerging countries in an attempt to better reconcile development demands, conflict over energy resources and increasing environmental risks.

Growth in emerging countries and increasing risks

In terms of energy resources and environmental threats, the planet could not withstand an extension of the energy consumption seen in the major developed blocs (North America and Europe) to the powerful emerging blocs represented by China, India and Brazil. However, this seems to be already underway: over the last 15 years, almost 80% of the increase in world fossil fuel production, especially oil, was used to meet the increasing demand for energy in emerging countries, principally in Asia and Latin America. Coal, on a par with oil, accounts for 40% of this growth in fossil fuel consumption in developing countries.

In relation to their share of the world's population (74%), the amount of the planet's fossil resources used by developing countries today (35%) remains minimal compared to that used by industrial countries. But if, as everything leads to believe, the pace at which the requirements of China, India and Brazil are developing continues for another 20 or 30 years, and is applied to a growing number of emerging countries, especially in the rest of Asia and Latin America, then the geography of energy requirements and trade flows will be profoundly altered.

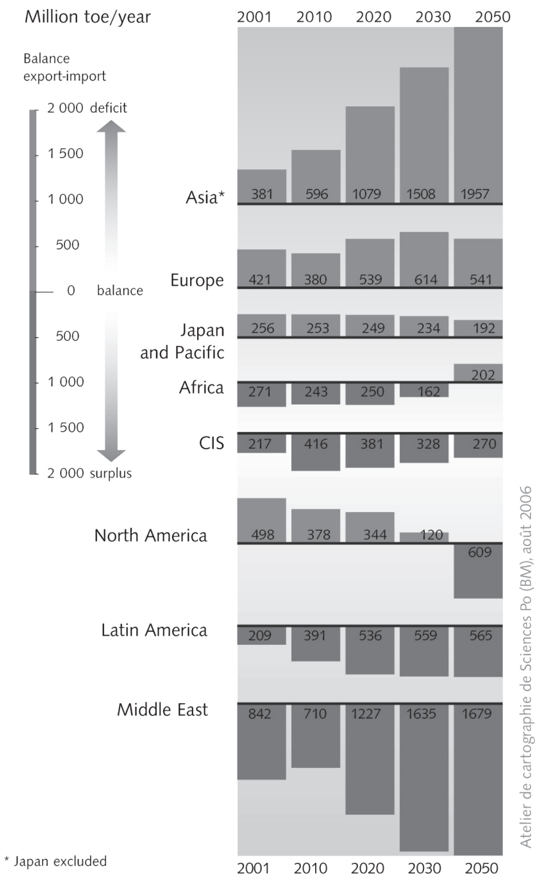
In business-as-usual scenarios established using the POLES model[a] for the European Commission (*World Energy Technology Outlook*-H2), developing countries, which currently consume 1.5 times less energy than developed countries, will consume over 1.5 times more by 2050. There is no doubt that their economic and geopolitical repercussions will be considerable, as illustrated by the projection of oil import and export balances by region (Figure 1, next page).

The immense brown haze hanging almost continuously over most of Asia gives an initial indication of the environmental cost of energy growth in Asia. But in a certain sense, this remains a regional problem that interferes only marginally with the rest of the planet. But the same cannot be said for greenhouse gases. According to the aforementioned reference projection, global CO_2-energy emissions could more than double by 2050, rising from 5.5 to 12 Mtce per year, with those of developing countries increasing five-fold over the same period. Although the responsibility of industrial countries in these emissions remains overwhelming, the expected energy growth in major emerging countries, however legitimate, presents the whole world with an unprecedented environmental challenge.

In addition to competition over resources, energy growth in emerging countries will also go hand in hand with considerable investment and financial requirements for energy infrastructure, especially for electricity. The previous projection implies a fourfold increase in the world's electricity production capacities by 2050: this represents 360 000 MWe to be built every year, or 350 billion euros of investment required annually for power plants, and almost the same again for network infrastructure.

The international financial system is capable of mobilizing funding on this scale, given the economic growth predicted. Questions may be asked, however, as to the economic, institutional and political conditions likely to guarantee both the return on such investment and financing that is suitable to the requirements. The choices made by emerging countries in terms of market liberalization will undoubtedly be decisive. Certain recent crises (California, Brazil) have shown, for example, the limitations of those market models where sales prices cannot guarantee the return on investment.

FIG. 1 **Oil import and export balances**



Source: B. Chateau from WETO, 2006

The global picture painted by these projections is therefore worrying. But they must not be taken as predictions. Their principal value is in drawing attention to the consequences of progressively extending the current ways of life and production systems of industrial countries to emerging countries.

However, things are likely to be very different: the probability of these developments causing conflicts of interest between the major regions of the world means there will almost certainly be either a radically different conciliatory approach (if these conflicts are sufficiently anticipated and managed collectively), or a conflictual solution with winners and losers (if they are not). The quest for sustainable development ties in with conciliatory solutions to these conflicts of interest – the only solutions capable of guaranteeing one and all the right to development. Other forecasting scenarios can be used to explore the content of such solutions and the conditions under which they can be achieved.

Development and energy: plea for a review

Most energy forecasts for developing countries, especially those of the IEA, are based on the reproduction of a development model extrapolated from the one OECD countries have experienced for over a century. Above all, they reproduce the way in which economic growth has led to increasing energy requirements, when in actual fact the soundness of this relationship should be called into question in view of the future of developing countries.

Re-examining energy intensity

The concept of energy intensity is at the heart of the representation of the link between economic growth and energy growth. Past energy intensity curves for industrial countries over the last century are bell-shaped[1], and are generally interpreted as follows. Industrialization, the first phase of development, gives rise to more rapid growth in energy needs than economic growth and energy intensity increases along with GDP. In the second phase of development, service activities, which consume less energy, gradually take over from industrial activities in GDP growth. Energy growth gradually slows down in comparison with GDP: energy intensity reaches a ceiling, and then begins a steady decline.

Comparing industrial countries shows that the earlier industrialization began in a country, the earlier and higher the energy intensity peak. Some see this in terms of a decline in energy intensity peaks over time: *the later the industrialization process begins, the lower the intensity peak will be.* By predicting the industrial emergence of developing countries, it could thus be possible to gain a clear indication of the future relationships between economic growth and energy requirements. But is this really the case?

Declining energy intensity peaks are generally explained using a technological argument. Thanks to technical progress, information management and their political transmission via energy conservation, experience shows that less and less energy is needed to generate one unit of GDP, other things being equal. Given that technology is increasingly being shared worldwide, this effect is seen in all countries, even the poorest ones: thus, the later countries emerge, the more globally efficient technology will be, and consequently the lower the peak will be. Some believe that energy efficiency policies may even be sufficiently powerful incentives to 'dig' a tunnel in the energy intensity peak (known as the 'tunnel effect[2]', thus allowing the countries concerned to bypass the highest intensity phase.

The form of energy on which the industrialization process is based must also be taken into account. Emerging countries principally use oil and gas for their industrialization[b], which are more efficient forms of energy than coal, on which developed countries based their industrialization.

These technological arguments, however solid, explain only part of the energy intensity ratio: its numerator, energy. Economic development models and the forces motivating growth must also be examined. What can be said about the denominator, GDP? The monetary standard of economic development, GDP is linked to energy requirements in two ways:

- it depends on the quantities of goods and services produced and consumed using energy (tonnes of steel, cars, etc.): this is the 'volume' effect, which has just been shown to evolve with the different phases of industrialization;
- it measures the wealth created and therefore not only the ability of economic agents to purchase the goods and services produced, but also their quality, their use and the energy associated with them (fuel for a car, electricity for air-conditioning, etc.): this is the 'wealth' effect.

The respective weight of these two effects depends especially on the way in which value is extracted from the quantities produced. In other words, the evolution of energy intensity also reflects the overall evolution of the price system. This lies at the very heart of the economic development model, in terms of both the way in which prices are determined and relations with the outside world. For example, the spectacular reduction in China's energy intensity in recent years could be the result of a considerable improvement in its energy efficiency. But it could also reflect a tremendous wealth effect following the transition from a planned economy to a market economy.

Putting people back at the heart of the debate

In order to fully understand the relationship between development and energy, it is essential to first put people back at the heart of this relationship. Ultimately, energy is only consumed in order to satisfy individual needs, either directly, as for air-conditioning or mobility, or indirectly, to produce goods and services. But people are also the prime factor in the production and creation of wealth, providing them with the technical and financial means to satisfy their own needs. In the energy intensity ratio, people are the prime determinant of both the numerator (energy) and the denominator (GDP).

The first issue is therefore population growth, which has a direct, mechanical impact on both energy requirements and the production and creation of wealth. What is its effect on the ratio of the two, energy intensity? The relationship between population growth and economic growth is of course more complex than a simple volume effect.

In addition to the number of people, several major factors come into play:

- *the active working population*, in other words the share of people in paid employment in the total population. This share is chiefly determined by the age structure and the social regulations in force (child labor, retirement), and the effective rate of paid employment for this population is largely determined by the stock of productive capital in place;
- *the time devoted to paid work*, since it is the overall volume of hours of paid work that truly conditions the production and creation of wealth. This time is largely dependent on the social and cultural regulations in force (length of the working day, holidays, etc.), which are reflected more clearly by major national negotiations concerning the use of time. This arbitration between time spent working and time available for consumption inevitably has an impact on the profile of the needs to be satisfied, and consequently on energy;
- *employment productivity*, in other words the ability to produce and create wealth for one hour of work. This is as much a matter of the technical capital in place as the ability to use it: whereas globalization means technical capital is being brought into line, the same cannot be said for the level of employee training, which takes a long time to change and is strongly influenced by the evolution of the age structure. For emerging countries in the final phases of demographic transition, low levels of training in previous years may act as a significant brake on future increases in productivity, especially in countries that have a restrictive attitude towards women in this field.

Information is globally a powerful determinant of the efficiency with which energy is produced and consumed[3]. The issue here is not so much the energy efficiency of technical capital in general, but rather the efficiency of the technical capital truly installed, and of that with which this capital is used. Thus, increasing the level of employee training speeds up the production and creation of wealth (productivity effect) and slows down the growth of energy consumption (efficiency effect), causing the progression of energy intensity to slow down and then decline more and more rapidly. This is another explanation for the aforementioned bell-shaped curves for energy intensity in industrial countries.

Initial training is at the heart of development policies in most of the countries of the world. There is no doubt that access to higher levels of training is still limited in many cases, but economic growth is establishing a virtuous circle in this field, which should dominate the progression of training in a large part of the world in the decades to come, albeit on a lesser scale in certain countries whose social and cultural policies intentionally limit access to training (especially for girls). Bringing levels of training and information into line will have considerable consequences everywhere, on both employment productivity and energy efficiency.

Demographic transitions

Demographic transition is observed in all industrial countries and a growing number of emerging countries, resulting in a shift from a family model based on numbers (households of five people or more, on average) to a family model based on the economy (households of less than three people, on average).

Linked to materialistic values, which go hand in hand with economic growth, demographic transition is now over in most industrial countries and in socialist emerging countries, including China. These countries are expected to see their populations decline in the decades to come, with a rapid distortion of the age structure in favor of older people (with the dwindling share of the working age population), an upsurge in the share of households of one or two people and the continuation of urbanization.

For developing countries, either demographic transition has already begun, especially in the other emerging countries, or it should begin in the next 20 years. These countries are still likely to experience high population growth. India is thus expected to become the most populated country in the world, ahead of China; the population of Africa could explode by 2050 if the major current diseases – responsible for high mortality – are halted quickly enough. The share of the working age population will rise everywhere, with no guarantee that opportunities for paid work will increase at the same pace due to social and cultural pressure and financial obstacles.

In industrial countries and the major emerging countries, the next few decades will see major friction concerning the use of time: longer working hours, and therefore more wealth, but less time to enjoy it ("lack of time" stress[4]), or more free time, but fewer opportunities ("lack of money" stress). The ageing population, with the resulting increase in time spent working, goes against the grain of history, which is one of a constant quest by workers to reduce this share. The way in which this confrontation is resolved will have major consequences on the dynamics of energy requirements, especially the development of mobility.

For the other developing countries, the dominant trend for some time will remain the shift from time spent procuring food in traditional rural systems towards time spent in paid employment, which is more concentrated in urban areas. This will have two major consequences in terms of energy: an increase in the production and creation of wealth, with the corresponding increase in energy requirements; and population migration from rural areas to towns, where the way of life generates incomparably higher individual energy requirements.

Another outlook on energy requirements

This analysis naturally leads to a characterization of energy service requirements according to the major sociocultural functions (Box 1). Several striking developments can be observed in this field.

The first is the *rapid growth in energy service requirements for food procurement* associated with the reduction in time devoted to this function (requirements in the agri-food production system, requirements within households)[c]. Overall requirements are expected to double at the world level, whereas the population will only increase by a third. This growth will be accompanied, especially in developing coun-

Box 1

New concepts for understanding very long-term requirements

Understanding requirements from a very long-term approach depends on concepts for fully grasping ways of life and behaviors, *independently of production systems and energy uses* as they are known today.

Energy products are never used for themselves, but rather for the service they provide: comfort, food preservation, mobility, etc. The 'energy service requirement' thus describes what individuals have the right to expect on account of their belonging to a specific sociocultural, economic and physical environment. This requirement is generally defined in strict reference to the elementary functions of economic, social and cultural life, gathered into five major 'sociocultural functions': food, housing, work, accomplishment and movement.

Energy services combine different uses of energy: thermal comfort, for example, includes heating, ventilation and air-conditioning, etc. They require different technological packages, defined by specific energy products and types of equipment, upon which they generally impose certain conditions (unit power, continuity/intermittence, quality, spatial density, etc.).

In order to measure, compare and combine such diverse energy service requirements as individual motorized transport and irrigation, for example, they are expressed using a common unit: the joule of useful energy needed to satisfy these requirements in the current technological context. This measurement is not to be mistaken for that of the physical energy requirements to be satisfied: the physical equivalence between the energy needed for the same service today and at the time in question can only be established if the technological paradigm implemented in response is defined in the prospective scenario.

tries, by a move towards increasingly concentrated services (industrialization and urbanization) and services requiring high 'energy availability', or exergy, such as food preservation, etc.

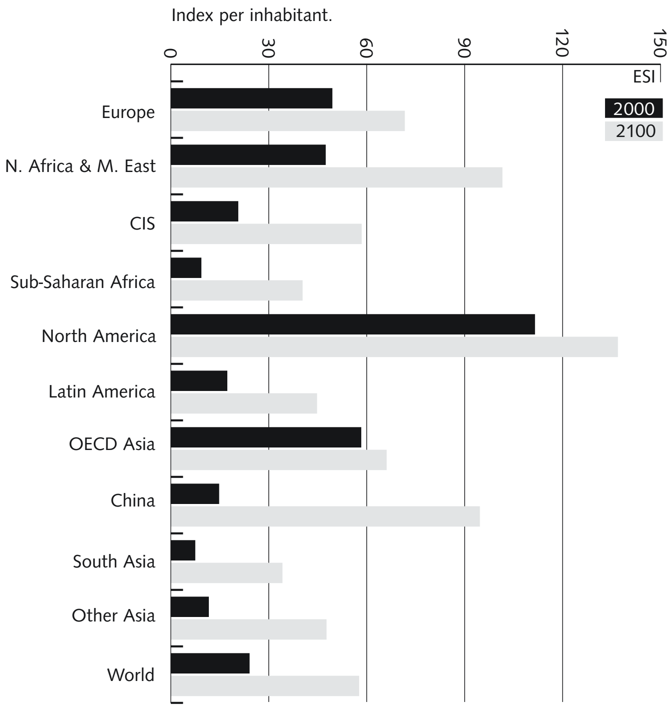
The second major development is *the expected explosion in mobility in developing countries* (more kilometers covered more quickly), which could see corresponding energy service requirements increase five-fold this century. According to Zahavi's hypothesis, people all over the world and at all times spend an average of one hour per day traveling[5]. As their income increases, they attempt to extend the area they can cover within this time constraint using more and more rapid means of transport: horses, bicycles, buses, trains, cars, high speed trains and planes. The history of the OECD suggests a close relationship between average traveling speed and GDP, linked to past dynamics of motorized travel in these countries. If extended to the rest of the world, this would mean an inevitable explosion in mobility service requirements. However, the social and individual functions of mobility are not fundamentally expressed in kilometers to be traveled, but rather in terms of freedom of movement and accessibility. The issue here is not going further and faster or less far and less quickly, but that the ultimate satisfaction is the same for equivalent costs.

The third important development, which primarily concerns industrial and major emerging countries, is *the increase in leisure time and its consequences* on energy service requirements. The first is *the explosion in information and communication* equipment and the corresponding electricity requirements, which could be increased 16-fold by the end of the century. The second relates to *tourism*, especially opportunities for remote tourism provided by increasing wealth, a potential channel for a significant increase in air transport and corresponding energy service requirements.

Otherwise, energy service requirements linked to the housing function, which respond to the almost continuous pursuit of comfort, appear to be limited only by the financial constraints of economic agents, if the history of the OECD is anything to go by. The *role of prices* therefore appears to be central to the dynamics of these requirements, with weather conditions having a greater influence on the structure of requirements than on their volume, for the same level of financial constraints. At current energy prices, these requirements could triple at the world level in the next century, once again with strong spatial concentration (urbanization) and higher demands in terms of exergy (air-conditioning, lighting, etc.).

Globally, energy service requirements (measured according to current technical conditions) could see a 2.5-fold increase this century, with profound changes in their geographical distribution in comparison with the current situation (Figure 2)[6]. These developments are accompanied by major changes in technical terms: diffuse, low power requirements with low quality demands could thus be halved, with a considerable decrease in highly concentrated requirements with high unit power, compared to a 70% increase in spatially concentrated but low unit power requirements, with high quality demands.

Fig. 2 **Energy service requirements**



Source: B. Chateau, from VLEEM

Energy paradigm(s) and sustainable development

What are the limits to the development of the current energy system in view of this increase in energy requirements? What would be the implications for the major emerging countries of Asia and Latin America?

The first constraint concerns resources, seen in the existence, according to Hotelling's law[7], of an impending peak in annual global oil production before its inevitable decline. The date at which this peak oil will occur is still subject to controversy, linked for example to the expected development of non-conventional oil (tar sands, oil shale, extra-heavy oil) and a potential separation between economic growth and energy requirements. But experts generally agree that this peak will occur before 2050, with some setting it well before (in 2020 or even 2010).

According to this vision, if nothing is done beforehand to anticipate and gradually accompany this foreseeable 'decline', it will rapidly become a source of fierce competition over access to oil. Considerable economic and geopolitical impacts should therefore be expected, capable of breaking the development motor in many parts of the world. Current Chinese and American strategies regarding the Middle East and oil-producing countries in general give a foretaste of the price to pay for this laissez-faire attitude.

In addition to the limits of resources are global environmental limits, with climate change at the forefront. Today this concern and the policies aimed at dealing with it are essentially the responsibility of industrial countries. But all projections agree that the major emerging countries will rapidly have to fall in step, failing which extreme weather events can be expected, or even a serious clash between industrial countries and developing countries under the pretext of saving the planet. The dates at which these major problems will occur may vary according to the pattern of energy requirements in emerging countries, but the risk is clearly that the development of a large number of Southern countries will be hindered.

The third potential limit concerns financing. According to the current paradigm, responding to a growing concentration of energy requirements, with higher quality expectations, requires more and more investment per toe of energy consumed to produce, transform, transport, store and deliver energy. But in order to guarantee access to energy for individuals and professionals – considered indispensable to development – it is tempting to limit the cost (either by resorting to fierce competition between producers, or by means of price control, if necessary using subsidy mechanisms). However pressure to reduce energy prices may prove incompatible with the rate of return on investment demanded by private investors or the major financial establishments. The conflict between these two demands may also act as a brake on development.

What kind of development is possible in the current energy system?

To paraphrase Bernard Laponche, there are in fact strong presumptions that "*this model [OECD] and this energy paradigm are incompatible with sustainable development*". While certain authors play down the importance of this incompatibility[8], studies exploring the options available within the framework of the current paradigm show that they are based on highly restrictive conditions and the uncertain development of technical solutions to particular problems. Projections based on the aforementioned POLES model and the VLEEM project shed light on these issues for 2050 and beyond respectively.

These projections produce a vision of the state of energy in the world by 2050 based on the pursuit of the current paradigm, with no heavy constraints regarding the greenhouse effect. It concludes that resource limits for oil and gas could be overcome by means of high price rises. It describes a world in which, among other things:

- Asia alone consumes and imports more hydrocarbons in 2050 than all industrial countries today;
- coal, for which known resources are far more extensive than for oil and gas, becomes the world's leading fossil fuel;
- the center of gravity for the international oil and gas trade moves far to the east of Europe.

After 2050, the VLEEM project shows that lasting development in developing countries based on fossil fuels remains possible until at least the end of the century, with coal increasingly establishing itself in all parts of the energy system, except for several areas where oil will remain very difficult to replace at acceptable costs, including air transport.

In general, these studies envisage the pursuit of growth in demand based on the same relationships with economic growth as those observed in industrial countries in the past. But they also insist on the fact that climate and resource constraints can only be overcome by means of an increase in the technical efficiency with which energy must be used, which without calling into question the foundations of the current paradigm, will be no less significant: very well-insulated new buildings, highly efficient vehicles, etc.

These studies therefore describe the characteristics of a fossil fuel paradigm considered sustainable. In this vision, more and more coal is used to deal with limits to resources, representing up to 70% of primary energy consumption. The problem of the greenhouse effect is managed[d] by closely linking two developments:

- the massive progression of zero-carbon energy carriers in final uses (electricity or hydrogen essentially produced using fossil fuels), development consistent with changes in the structure of energy service requirements;
- capturing and storing the CO_2 produced by large combustion plants and energy transformation equipment, which will increase with the move to zero-carbon carriers. This implies mastering storage in deep aquifers at reasonable costs, making it possible to store up to 60% of emissions.

But this presupposes a number of things: that all fossil fuel producing countries will be willing to produce and export the quantities demanded at the right time and without restrictions; that the technical and economic management of CO_2 sequestration will be effective at the required time for considerable storage volumes; and that all consumer and producer countries will set up the institutional conditions and market mechanisms needed to guarantee an acceptable rate of return on all the investment required.

However, observations made today hardly inspire optimism. Current tension on the oil market stems partly from the reluctance of Gulf oil producing countries to significantly increase their production to meet growing world demand at a price corresponding to market fundamentals. In other words, the availability of reserves that are technically and economically exploitable is no guarantee that production will align itself with requirements. Finally, the blackouts that are sometimes associated with electricity sector liberalization show that here again, supply does not automatically adapt to demand.

What are the energy alternatives for development?

There is no guarantee that Southern countries will be able to pursue their development, especially sustainable development, within the framework of the current energy paradigm. Other futures must therefore be contemplated, based on alternative energy paradigms, and the conditions needed for their emergence must be examined. Two alternatives are generally considered on the scale of a century: nuclear and renewable energies.

But firstly, is it really a question of alternatives, or simply of different fuel mixes, with varying levels of nuclear or renewable power?

The 'fossil fuel paradigm' in fact refers to a dominant technical system based on combustion, which imposes specific technologies in order to meet requirements, a specific organization to produce, transport, transform, distribute and store very particular energy products, and even specific behaviors induced by the technologies used. Until the mid-20th century, industrial structures were shaped by the coal/steam engine combination, while urbanization and spatial planning have since been shaped by the dominant oil/internal combustion engine combination.

In this sense, as they are currently used, nuclear and renewable energies fit perfectly – albeit marginally – into the fossil fuel paradigm. However, things would be very different if nuclear energy became the dominant means of producing energy carriers (electricity, hydrogen), which then moved into all uses thanks to certain technologies (such as fuel cells), generating specific organization and behaviors (cars intended solely for urban use, for example). The same would apply if renewable energies became dominant, causing, for instance a complete revision of the design of buildings and their energy equipment to allow them to become autonomous (examples of which already exist) or to interact with others within a local micro-grid.

This implies technical and organizational developments that deviate completely from the dominant model, leading to fossil fuels in general, and oil in particular, being steadily pushed aside. *Oil will gradually be abandoned*, not due to a lack of resources, but simply because there will be less and less need for it (just as the Stone Age did not end due to a lack of stone).

Most developing countries are still far from being able to envisage a shift towards nuclear power, for two reasons. Firstly, it will be many decades before the nuclear industry is sufficiently safe, efficient and non-proliferating to be extended to the rest of the world without causing an 'Iranian' or 'Korean' syndrome, and to cope with the low level of uranium resources in the world. Secondly, the *highly capitalistic nature of nuclear power* makes it a poor choice for countries with a lack of financial capacities.

Renewable energies therefore appear to be *the most serious alternative to fossil fuels*. However, there is no room for dangerous utopianism. Despite being abundant, inexhaustible and very well distributed throughout the world, renewable energies come up against a fundamental paradox: the fact that they are generally diffuse and intermittent, or even unreliable (except for biomass), faced with increasingly concentrated requirements and ever greater quality expectations, in terms of both energy potential and continuity of service. This qualitative difference between supply and demand has a cost, which may sometimes be considered exorbitant.

Massive reliance on renewable energies is therefore only an option if the technologies, means of organization and behaviors implied by such a paradigm make it possible to drastically limit this cost. The foreseeable increase in energy service requirements previously described consequently seems highly encouraging. Moreover, in the renewable energy scenario, the rapid growth of energy service requirements is only partially based on increasing demand for commercial energy. This remains at levels compatible with solar, wind and biomass potential that respects land use. The concept of the autonomous solar building perfectly illustrates this development.

The cost of an energy changeover will be all the higher if the infrastructure in place, buildings, transportation and industrial platforms are developed and new infrastructure requirements limited. Fortunately, the opposite is usually true of developing countries. Major emerging countries, such as China, India and Brazil, could be among the first to take the plunge. They have the necessary elements (domestic market, industrial, financial and intellectual possibilities) to become world leaders in the production of technologies and integrated systems adapted to this new model.

The challenges

If it follows the model of industrial countries, energy demand in developing countries should see a tremendous upsurge over the next few decades, which may threaten the major balances in terms of both energy markets and the environment. However, it is not inevitable that developing countries will subscribe to the supply model and the fossil fuel paradigm underlying industrial countries. Firstly, the growth of their energy service requirements could be better managed. Secondly, alternatives to the fossil fuel paradigm exist, primarily based on renewable energies. These complex developments will not be achieved without considerable political efforts.

In the shorter term, the energy challenges facing developing countries will initially stem from the inevitable rise in fossil fuel prices. In addition to its direct impact through the balance of trade and the balance of payments, this price rise will encourage the use of energy transformation technologies with a higher investment content and lower operating cost: efforts devoted to energy may then lead to crowding out in other sectors of the economy necessary to development. Furthermore, the price structures – especially for electricity – and commercial policies generated by the development of highly capitalistic infrastructure are likely to seriously impede the progress of energy efficiency, which is nevertheless the only weapon available to counter the harmful effects of increasing fossil fuel prices on the balance of payments.

Whether the aim is to encourage energy efficiency and the use of domestic energies, or to guarantee the return on increasingly capitalistic investments, energy prices to final consumers will be the sinews of war. Here again, there is a considerable challenge: market structures capable of convincing investors must be reconciled with institutional mechanisms capable of taking into account long-term development demands and policies aimed at protecting the most disadvantaged populations. This requires a subtle interplay between respect for competition, taxation and subsidies, whose outcome is often uncertain, as demonstrated by some of the recent crises in the electricity sector.

[a] The POLES model is one of the principal international references for the world energy sector. It is based on the principle of partial equilibria: supply/demand equilibrium for the major countries and regions of the world; supply/demand equilibrium for the major energy markets of the world.

[b] China and India are notable exceptions. Coal could once more play a major part, while gaining in efficiency (cf. chap. 3, Martin-Amouroux).

[c] In the United States, food procurement absorbs 27% of total energy consumed, and in France 21%.

[d] In the sense of a stabilization of concentrations of greenhouse gases in the atmosphere at less than 650 ppmv of CO_2 equivalent. Industrial countries reduce their emissions by 10% every 10 years from 2010 onwards, and developing countries follow the same pattern once they have reached the 1990 level of development of industrial countries.

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The high growth observed in China's power sector, thus far dominated by the use of local coal, is both a key challenge for the country's economic development and a test for the control of greenhouse gas emissions in emerging countries. Despite uncertainty surrounding the outcome of reforms underway, measures may be taken to reverse the evolution of the sector. Defining a suitable cooperation framework would make it easier to implement such measures.

Diversifying power generation in China[1]

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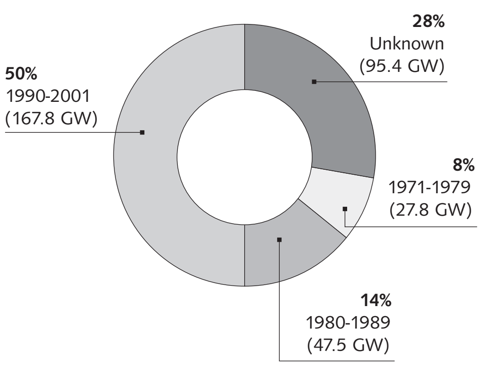
The People's Republic of China was founded in 1949 with only a primitive 1.85 Gigawatt (GW) electricity industry. It has since grown into the second largest electric power system in the world with an estimated installed capacity of 531 GW in mid-2006. These figures represent a remarkable increase from well below 400 GW in 2003 and a reported 442 GW in 2004.[2] The number of people who have no access to electricity has been reduced from 245 million in 1979 to around 20 million, less than 2% of the population. Nationwide, average per capita power consumption is about half the world level, and in China's largest cities the power system is up to world standards. Development has been particularly impressive since the boom in investment began in the 1980s. According to industry accounts, an estimated RMB 1 107 billion (US$134 billion) was invested between 1981 and 2001 in new generation and delivery capacity. Three-quarters of this sectoral capital came from domestic sources, with foreign investment, mostly from offshore Chinese sources, making up the rest.

Since the end of the last period of relatively weak economic growth (1999-2003), the rate of expansion of Chinese electricity generation has been astronomical. It has far outstripped projections made only a short time ago (compare Figure 2, next page). While official statistics that chronicle this increase in installed capacity remain uncertain, the best estimates are that new generation capacity reached at least 50 GW in 2004 and 60 to 70 GW in 2005, reflecting rising production of 14.9% between 2004 and 2005 alone.[3] In June 2006, it was reported that China's total installed capacity was 531 GW, with more than 70 GW of newly installed capacity to be placed in service this year and approximately 250 GW in new power station projects under construction.[4] There is substantial debate about whether this rate of power sector growth can be sustained or whether surplus capacity will become apparent in the years after 2008. The answer to this question will depend on the overall rate of Chinese economic growth and on the trajectory of energy intensive sectors such as heavy manufacturing or transportation.[5] Official estimates of the demand for power consumption expect a rise of less than 7% annually over the next five years, down from annual increases of at least 10% during the past five.[6]

However, these official targets have regularly underestimated the actual rate of power expansion. Recent experience on the ground is that the rate of increase for electricity capacity and use has been faster than that of the economy as a whole, mainly because electricity is being substituted for direct combustion

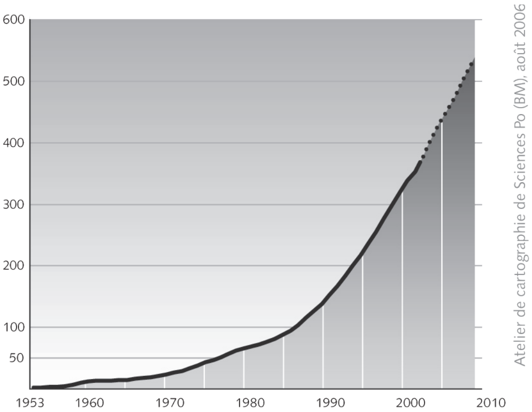
Fig. 1 **2001 Capacity by commission date**



Source: China Electric Power Yearbook

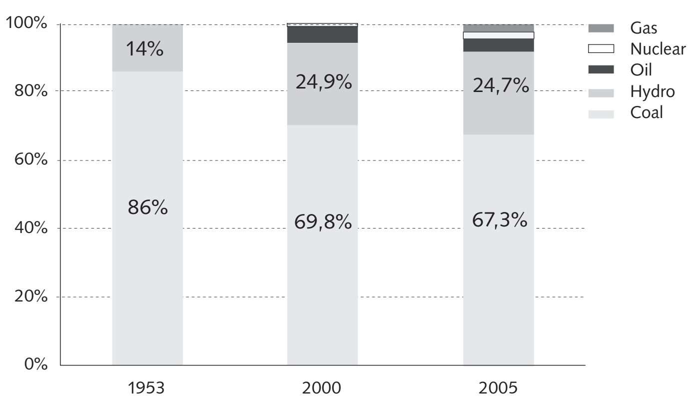
of other fuels and higher wealth has raised demand for electric appliances, including residential and commercial air conditioning. Moreover, the historically exceptional record of declining energy intensity during the period between 1990 and 2003 seems to have been reversed in the high growth years since.[7] If the Chinese economy grew between 9 and 12% annually from 2003 through 2005, electricity growth was most likely increasing at 13 to 16%. This implies that unless Chinese overall growth falls sharply in the coming decade, the financial, regulatory and environmental consequences associated in this paper with earlier high growth periods will continue to characterize the Chinese electricity sector and pose spillover issues for the wider global system. Current rather conservative models estimate Chinese electricity demand will grow from 112 million tons of energy (toe) to 478 million toe in 2030, with a consequent doubling to tripling of attendant NO_x, TSP and CO_2 emissions.[8]

FIG. 2 **Generation capacity (1953-2010)** [9]



Source: China Energy Yearbook

FIG. 3 **Capacity fuel structures**[12]



Source: China Statistical Yearbook; 10th Five-year plan; Study of 2002 Electricity Industry Development (January 16, 2003) (http://www.drcnet.com.cn).

The Chinese electricity industry has always been dominated by local coal and, secondarily, hydropower (figure 3). This reflects proximity and, since 1949, a long-term energy policy that emphasizes energy security through the promotion of indigenous energy resources. This same policy has put enormous strain on China's energy transport infrastructure. While China's coal resources are abundant, quality coal for power generation is concentrated in the north, far from the load centers in the eastern and southeastern coastal areas. Thus coal accounts for 40% of annual railroad and one third of annual river and sea freight transportation. While China's hydro resources are abundant, their distribution is predominantly in the west, also widely removed from the coastal centers of demand. Development of hydropower has been slow due to the lack of funding and inadequate technologies for large hydropower stations.[10] Almost 80% of exploitable hydro capacity remains undeveloped.[11]

More recently, Chinese energy policy has begun to look to alternative energy resources because of coal's adverse impact on the environment. Hydroelectricity is assuming new policy importance, which also serves the government strategy of investing in the poorer Western regions. Including the 2009 completion of the 18 GW Three Gorges Dam, China's Hydro Electric Corporation is at present developing or planning more than 60 GW of new capacity.[13] Moreover, the government now proposes to expand the use of natural gas for power generation. The first nuclear power plant, the 300 MW Qinshan (Phase One) in Zhejiang Province, was commissioned in 1992. As of 2005, 11 nuclear reactors were to be operating in China, with a combined 8+ GW capacity. Another 26 units with a combined added capacity of 23GW were planned to become operational by 2025, although more recent government targets have suggested a revised goal of 40 GW by 2020 that would account then for 4% of total capacity. As discussed in more detail later in this paper, in 2005 the two initial units of China's first commercial gas-fired power plants were brought on line. Both plants burned gas from China's Tarim Basin, delivered by the new 4 000 km East-West pipeline, which could supplant the equivalent of nine million tons of standard coal per year in new power plants. An additional 18.4 GW of incremental piped and liquefied natural gas (LNG) fired electricity capacity are under construction, contributing to a total planned increase of 60 GW (approximately 6% of the nation's installed capacity) of gas-fired power by 2020.[14]

China's central energy planning authorities have also placed particular emphasis on improved energy efficiency and the development of non-hydro renewable power. Wind projects for more than

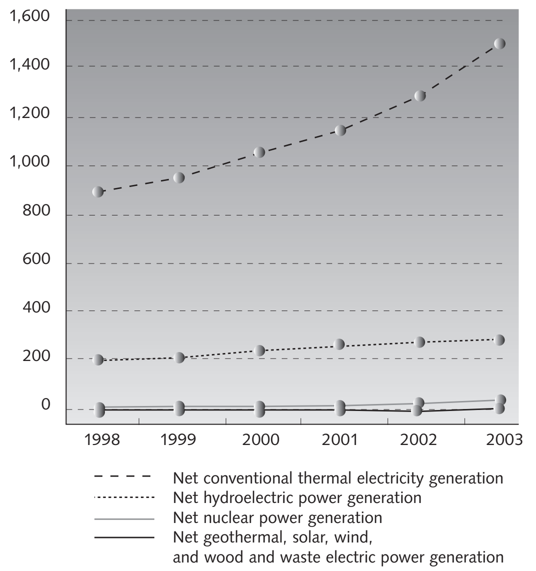
150 megawatts (MW) and rural solar module programs of approximately the same total scale have been launched.[15] Given the still relatively high energy intensity in many Chinese industries and power plants, the avoided costs of demand side measures often make such policies purely economic in comparison to the costs of incremental generation construction. Recent preliminary scenarios suggest that with liberal enactment and enforcement of energy and environmental policies that mandate industrial technology upgrades and subsidize renewable power production, a demand reduction of 280 million toe (against a projected baseline of 2.7 to 2.9 billion toe consumed) and a growth of renewable production from approximately 200 to 300 million toe would be feasible.[16] However, it is also important to note that while prior to 2000 the share of coal in total energy use declined to 66%, under the strains of recent higher growth, it has again increased to between 76 and 77% in the period 2002-2004 and is estimated to remain the dominant fuel in coming decades.[17] Even with best case savings of 400-600 million toe of polluting energy from extensive energy efficiency measures, China's fossil fuel energy use will still more than double from its 2004 base of 1 320 million toe.[18] And, as is evident from figure 4, given the scale of the installed base of fossil fuel-fired power in China, even very strong policy mandates that compel large percentage increases in alternative power production will not alter the basic composition, or the attendant environmental and security risks, of China's power profile.

Between 1949 and 1990 the Chinese government consistently put emphasis on heavy industry. Indeed, the industrial (manufacturing) sector accounted for over 80% of national power consumption in 1980. It continued to be the largest user in 2000, although broader economic reform in the past 20 years has catalyzed development of the service sector and also higher residential power consumption (figure 5). Unlike some other leading developing countries, such as India, China's power consumption in agriculture is very small (about 4% today), which reflects the high cost of power and the fact that farmers are not a politically powerful group in China.

Rapid expansion of predominantly coal-based capacity and power generation has had severe environmental effects. By 1998, the power sector used 450 million tons of coal (25% of national coal consumption), emitted 6.97 million tons of SO_2 (30% of the national total) and 25% of the national total of CO_2 (Zhu, et al., 1999). It was also responsible for 80% of national NO_X emissions (DRC, 2002, p. 71). SO_2 has been the most harmful, with national economic damage estimated at between $7 and $13 billion in the mid-1990s.[20] Chinese CO_2 emissions from fossil fuels have grown rapidly from 2 940.49 million metric tonnes in 1998 to over 3 540.97 in 2003. They are projected to account for 21% of the world's CO_2 emissions by 2020.[21]

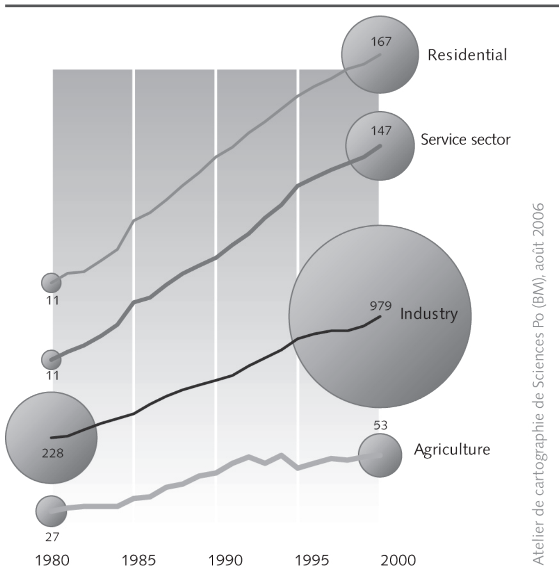
Chinese policy makers have enacted a number of environmental protection laws and regulations to address the problems associated with power production and to improve efficiency.[22] While enforcement has been weak, some progress has been made through policies that have had ancillary environmental benefits. For example, increased prices for electricity use in industry and de-emphasis on heavy industrial

Fig. 4 **Net energy generated by source 1998-2003**



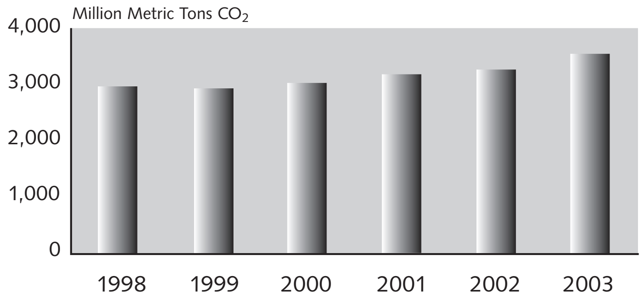
Source: International Energy Outlook 2004.

Fig. 5 **Electricity consumption by sector[19]**



Source: China Energy Statistical Yearbook.

Fig. 6 **Chinese carbon dioxide emissions from fossil fuels: 1998-2003**



Source: http://www.eia.doe.gov/environment.html

growth have reduced energy intensity (Sinton and Fridley, 2000). In addition, the recent long-term policy shift to diversify fuel sources has favored cleaner sources (notably gas, nuclear, hydro and renewables). Finally, the central government produced environmental gains when it shut down many small, old (and dirty) thermal power plants in the late 1990s to alleviate the economic effects of the unforeseen power surplus on state-owned generators. According to State Power Corporation (SPC) data, a total of 10 GW of small thermal capacity was eliminated between 1996 and 2000 (SPC, 2002). Recent announcements target the closure, admittedly far more problematic to enforce in a period of growing demand, of another 15 GW of older, inefficient coal-fired power plants over the next five years.[23]

Institutional reform

In the last 20 years, the Chinese power sector has experienced remarkable transition and institutional reform – a process that remains unfinished and uncertain. With the founding of the People's Republic of China in 1949 and the adoption of Soviet-style administration of the economy, the government nationalized all industries, including electric power, and instituted five-year central planning with the goal of promoting industrialization. The central government planned the scale and location of all power projects, provided the funds for infrastructure expansion, operated the system and set the priorities according to which end users were allocated electrical services. State-owned enterprises (SOEs) were not autonomous firms so much as administrative mechanisms for executing plans, without independent corporate status or claims to financial returns. The industry managed to grow at an average rate of 14% per year between 1953 and 1979 because electricity was given strategic importance in China's industrialization, and was therefore allocated massive resources from central government budgets. Despite growth, the industry was afflicted by the unavoidable flaws of central planning – economic inefficiency and, because prices were not accurate signals of cost, chronic shortage in power supply.

In 1979, the central government began sweeping market-oriented reforms that spurred economic growth, especially along the coast. Since the mid-1980s, reform efforts spread to the electricity sector, motivated by the hope of improving economic efficiency in the sector and the need to finance the added power delivery capacity needed to keep up with burgeoning economic growth. In many aspects power sector reforms have reflected the broader reforms of the Chinese economy that have gradually led to a declining state share of overall production and a reorganization of the residual state sector. Given the importance of energy to both growth and security, however, the Chinese central planning apparatus has been reluctant to relinquish control over the sector. At the same time, Chinese reformers have had an interest in what might be called a Western 'textbook' model of electricity reform that emphasizes the separation of generation from transmission and distribution, open competition in the generation sector, and independent regulation of sectoral operations. In spite of this professed interest, the actual record of change has been far more modest and complicated than the textbook would suggest.[24]

Electricity reforms in China can be divided into three stages. The stages correspond principally to different organizational reforms that have been instituted in the search for capital and performance. Beyond the shifting currents of organizational reform, the development of China's electricity sector can best be explained by the overlap of organizational reforms with broader macroeconomic cycles. These cycles have led from a critical shortage of electricity supply (1985-1997) to a brief period of lower demand when electricity was in glut (1998-2002), and finally to the current period of high renewed economic growth and a shortage of supply additions (2003-present). During long periods of shortage, Chinese reforms focus on getting new power on line as quickly as possible, and delegate much of the task of adding capacity to provincial and local authorities – a policy that has often pushed textbook reforms well into the background. During the period of surplus supply, political controversies sprung up over which plants would be dispatched; the central government used these controversies to reassert its authority and also to initiate planning for further organizational reform.

The first reforms specifically aimed at the power sector date to 1986 when the central government partially decentralized investment authority. Local governments, state-owned industrial enterprises and even private (including foreign) investors were invited to build new power plants that would supplement the state power system and help to satisfy surging demand. To make incremental investment attractive, the central government adopted a 'cost plus' tariff for these new plants, which permitted accelerated capital recovery and promised investors a competitive rate of return. In addition, various electric power construction and user fees were added to most end-user tariffs to fund still further investment and expansion of the power system.

This initial phase of organizational reform (1986-1997) successfully broadened sources of investment and raised badly needed capital for the electricity sector. Moreover, the reform changed the landscape of the electricity industry from a system exclusively owned and controlled by the central government to a dual system. At the core remained the dominant state planning system; around the periphery emerged a decentralized generation system, owned by various levels of government (provinces to localities), industrial entities and private ventures.

A second stage of reform began in 1997 in conjunction with a fresh campaign for fuller transformation of the whole economy from planning toward markets. The focus of this second wave of reform was generally to separate government administration from business operations, which had been indistinguishable under central planning, and, in particular, to sort out the ownership of state enterprises among the central, provincial and local governments. The central government erected the State Power Corporation (SPC) in 1997 to manage the state electricity system and eliminated (in 1998) the once all-encompassing Ministry of Electric Power Industry (MEPI). It vested the SPC with MEPI's business functions and assigned the administrative functions, such as system planning, to other government agencies. The SPC was later corporatized into a Western-style holding company, with provincial subsidiaries that owned generation and transmissions assets across China.[25] Although not all former MEPI electricity enterprises were owned within the SPC portfolio, the more modern and efficient facilities developed through central planning in the first reform period were retained.

The SPC orchestrated in 1999 a limited experiment of wholesale market competition in six provinces. This experiment was partially prompted by the unexpected glut of electric power following the macroeconomic slowdown in the wake of the Asian financial crisis. The SPC hoped that market competition could help lower electricity prices and increase sales, at the same time dispatching the more efficient plants in its own network. Instead, the experiment was halted in 2001 because of the quick return to rapid economic growth and a tighter market for electricity, which absorbed excess capacity and alleviated any immediate pressure for competition. However, the slack market had exposed enormous economic inefficiencies that arose from a system that was operated by politicized, often conflicting agencies at different levels of government, revealing the flaws of the earlier organizational reforms. Those inefficiencies in system operations made it clear to the central government that the partially reformed industry needed further revamping.

Following intensive internal debate and international advice, the central government formally started the (still unfolding) third stage of electricity sector reform in December 2002. In theory, this third stage seeks to follow the 'textbook' model by de-integrating utilities and exposing the sector to market competition. The vertically integrated SPC was broken up and its assets distributed to two government-owned grid companies and five state generation companies. All are controlled by the central government except for the regional grid company in the south, which Guangdong Province controls. The reform has also created an autonomous government regulatory commission that, to date, has few actual powers. The government is still contemplating the wholesale market design, the scope of power and responsibility of the regulatory commission, the possible continuing roles of central planning (including retail tariff-setting), as well as the overall industry structure and other issues associated with a functioning electricity market. Below these debates, economic growth has pushed demand to unprecedented levels and capacity expansion has taken off in a largely uncontrolled fashion. As reform has stalled, new power plants have been constructed by a wide range of state and private firms, with every kilowatt dispatched as quickly as it becomes available.

In sum, two decades into China's power sector reforms, the structure of the Chinese energy sector is not yet determined. Since 1979 Chinese power sector reformers have been exploring a broad gray area between central planning and open markets. But there are few inviolable principles as guides in this uncharted space. Rather, a wide array of contextual factors and specific interests has determined the shape and speed of change. The two most influential factors in explaining the development of reform to this point are China's macroeconomic cycles and the central government's policies on the supply of state-controlled capital. During periods of high growth and strong demand for power, the focus of policy will be on capacity expansion. Conversely, in periods of macroeconomic decline, so far observed only once in the last two decades, we expect that the restructuring agenda will be reasserted and enforced by central government agencies that aim to protect their own assets, partly by assuring that their plants are dispatched.

While much of China's reform effort in electricity is largely symbolic or organizational, the reforms of China's electricity sector are more than just formalities. Certain features of the system have been largely immune to reform. Finance has continued to be overwhelmingly from public, national sources. Politics still trumps markets in every forum for setting energy policy. And the central state has maintained its control of the core system of generation and transmission. Yet other elements of the sector's organization have varied, which have lessened the once near-exclusive influence of the central government. First, the limited financial and political capability of the central government to keep up with growth in electricity demand during the period of high economic expansion has led to a partial relaxation of central planning and the emergence of more decentralized energy development to meet residual demand not satisfied by the national power system. Second, the reorganization of the core state electricity system has created a new type of dominant firm – which I have called elsewhere a 'dual firm' – like the five national generating companies in China. At the same time, these majority state-owned firms both retain extensive market power and political connections in Beijing and behave more like private firms with management autonomy and publicly listed shares.[26] In any further reforms of Chinese electricity markets, these national generation companies will exercise enormous political influence.

Looking forward

To this point, the third stage of reforms has largely repeated the experience of the second, by reorganizing enterprises in the core state system without actually implementing much redesign of the market. A potential first step toward competition in generation markets, the dissolution of the SPC into multiple state firms, has been subsumed by the rising tides of explosive economic growth, electricity shortage and easy finance through both expansive government credit and private profits. A frantic rush to invest in new capacity has also derailed further institutional reforms that were originally slated at the time of the SPC's de-integration. The central government (indeed government altogether) has lost control over the size and shape of the electricity sector. Market competition has been put off for now.

Although Chinese advocates of comprehensive electricity restructuring still hope to solve both efficiency and development problems of the power system through the discipline of markets, various factors cloud the future of the third stage reforms. Of these clouding variables, the most general is the underlying nature of Chinese political and economic reform. As was the case in prior stages, the consensus long-range goal of change is only loosely located in that wide middle ground between markets and state planning. The embrace of the specific propositions of the textbook model was always more a response to the problems thrown up at the central government by prior reforms than a particular commitment to the predominance of market mechanisms. Despite professed interest in markets, the central government is still populated with strong currents that reinforce planning, state resource allocation and economic intervention.

We have argued that Chinese pragmatism in reform leaves open space in which the specific speed and course of reform will be decided more by the macroeconomic context and the political interests of actors emerging from earlier changes than by textbooks reflecting principled commitments. This is especially the case in contemporary China, where analysts are mindful of the unhappy experiments in reform elsewhere in the world. Utility market reforms have proven more complicated than the textbook manuals would suggest. In most countries, political and institutional factors have confounded efforts to create well-functioning markets for electricity. Even the market reform designer, the National Development and Reform Commission (NDRC), has not indicated whether it will give up control over tariffs and administrative authority over power project approval.[27] This has led to worries among researchers that the new regulatory commission will never attain independence but, instead, will become another 'decoration' under continued government control.[28] What is already apparent is that China's reform strategy to move in the direction of market reform without abandoning state power will create continuing uncertainty about the rules that apply to the electricity system.

Next, although there will be cyclical and temporary gluts of electric power, at present China faces a pressing short- and medium-term need to increase generation and transmission and distribution (T&D) capacities. The Chinese record indicates that as long as overriding attention is paid to the need for infrastructure expansion, reforms that create uncertainty for investors will be on shaky ground. In the first reform period, when high growth prevailed, the problem was solved through substantial decentralization of administrative control over investment. This same response has also marked the years since 2003 and this writing (2006) during which almost 150 GW of new power have been added by public and private investors (at all levels of government) through both authorized and unauthorized projects. The enormous pool of earnings retained by businesses and informal financial markets produced by national growth levels of between 10% and 12% have made domestic capital available and inexpensive to these various investors in a new wave of expansion of the electricity periphery.

In addition to effective decentralization, the particular character of power sector reform is shaped by the slow rate of reform in official capital markets. Financial markets in China remain only weakly liberalized and strongly politically influenced. The new state-controlled dual firms in the core power sector have selective access to credit from state banks (along with smaller amounts of capital from politically controlled public security listings). Under the expansive Chinese macro-economic policy since 2000, liberal state bank credit has allowed state electric companies to avoid the discipline imposed by other finance sources such as local governments, foreign investors or competitive capital markets.

Foreign investors have been largely inactive in the recent expansion after the repudiation and renegotiation of their power purchase agreements during the power glut of the late 1990s. Still, easy access to cheap capital strengthens the market position of the new state-owned national generating firms and enhances the organizational advantages that those firms already possess in unstable, politicized markets. Ironically, with this combination of political and economic power, in the absence of any effective controls on oligopolistic behavior, an introduction of real competition in China could permit the same abuse of oligopolistic power by national generators that plagued California's failed effort to implement textbook reform of its own electric power.

Given the pragmatic nature of Chinese reform and the contingencies that affect its development, predicting the long run outcomes of this third stage reform will be highly speculative. However, the earlier efforts at reform suggest that substantial economic growth and the countervailing political interests of the new actors that have emerged on the periphery of the state system during the first stage of reform and at its core during the second and third will strongly shape its content and progress. In the shorter term, rising demand will induce rapid capacity expansion in the national or core power sector. This expansion will be inexpensively financed by state bank credit and securities issued by the new national generating companies under the broad guidelines of central investment planning. The core sector infrastructure will be primarily coal-fired, large-scale (600 MW), domestically manufactured plants, although some incremental gas-fired and nuclear capacity will be supported at the margins for reasons of energy security, environmental protection and the business interests of powerful corporatized state firms in the oil and gas sector. In addition, the central government will maintain its political commitment to the economic development of interior regions through the centrally planned construction of large-scale hydro plants and dedicated transmission lines, supported by offtake mandates to transfer power to eastern load centers.

However, thus far, incipient competition in partially reformed electricity markets has resulted more in political contests between the new Gencos seeking favorable plant siting, financing, and dispatch allocations than in the institution of open merchant operations. Policy that sets the rate of T&D investment and the corporate choices of the two national grid companies about how far and fast to integrate what have until now been fragmented power networks and will answer key questions about the relative scales and structures of the core and peripheral sectors. Although greater centralization of policy and better cross-regional integration of the Chinese power system would increase the potential for effective market competition, the substantial market and political power that could be brought to bear by the new state generating companies upon the rules and operations of emerging national markets could pose serious threats to their prospective efficiencies.

A thought experiment with natural gas

The International Energy Agency (IEA 2004) projects that China will develop 67 GW of gas-fired power between 2005 and 2020. Coal-fired power is expected by the IEA to increase to 560 GW (from 247 in 2002) by that same year. Imagine that China were able to substitute 50 GW of incremental coal capacity with an additional 47 GW beyond the expected 67 to reach a total of 114 GW of gas-fired power. Given the different capacity factors of coal and Combined Cycle Gas Turbine (CCGT) plants, overall projected generation would be identical. Yet, in the hypothetical case, greenhouse gas emissions would fall by 213 million tons per year, or about the same amount as the entire EU25's 8% emissions reductions commitments below their 1990 baseline under the Kyoto Protocol.[29] While the following discussion recognizes the policy and economic challenges of an imagined substitution of gas for coal of this magnitude, it should be noted that the construction of this scale of new gas plants does not pose financial or technological challenges that China would be unable to meet. The U.S. was able to finance and build the addition of 110 GW of new gas powered electricity capacity in the much shorter period of the first years of this new century.

In June 2005 the first unit of China's first commercial gas-fired power plant came on line in Hangzhou. Shortly thereafter, a second combined cycle gas turbine unit began to operate in a co-generation facility in Shanghai's chemicals zone. Both plants burned gas from China's Tarim Basin, delivered by the new 4 000 km East-West pipeline. As noted above, 21 further projects to provide 18.4 GW of incremental electricity capacity are under construction, contributing to a total planned increase of 60 GW of gas-fired power by 2020.[30] In addition to piped gas, many of the added plants are to be supplied by imported LNG. Beyond the two LNG re-gasification terminals already being built in Guangdong and Fujian, Chinese national oil companies have announced their intentions to construct 15 more, of which at least 5 are reported to have been approved by the National Development and Reform Commission.[31].

The Chinese government has announced plans to develop a national gas market of 200 billion cubic meters (bcm) annually by 2020. This target is five times the size of the current market, nearly all consumed in non-power end uses, of 40 bcm/year. It aims to provide 60% (120bcm/year) of this gas from domestic sources and import a further 80 bcm/year, either from LNG or piped from as yet undefined sources in Russia. While the scale of quintupling national gas consumption is daunting and demands a variety of reforms and initiatives discussed in this section, the official projections may underestimate the possible expansion in gas-fired power that would be available if greater reliance on imported LNG were considered. Since so much of the planned increase in supply comes from domestic sources, the official estimated demand for gas depends importantly on the relative prices of Chinese gas and Chinese coal. However, depending on a complex interplay of factors outside of China, lower cost importable gas may be developed that would allow increases in gas consumption for power consistent with the thought experiment described above. This implies that the ability of China to meet its planned gas market growth, or to go further towards the objective we imagine, will require not only well-designed domestic changes in the rules of the power sector, but complementary and contested decisions about energy security, fuel markets and where regulatory authority will be situated.

At present, there is a range of national policy issues that will determine the evolution of gas-fired power in China. First, under current conditions, energy security, in the problematic sense of energy self-sufficiency, is no less as central a topic in China than it has become in the West. Consequently, there is debate in Beijing about whether China should minimize its reliance on imported fuels, reserve its scarce gas resources for premium residential uses and rely, as it has in the past, on domestic coal for power generation. Second, there is not yet a clear pricing policy for gas-fired power. Indeed, gas is threatened in principle with the prospect of tariffs determined in competitive markets to a degree that does not yet characterize pricing for coal-fired power throughout China. Such prospects, especially in the absence of sophisticated use of environmental adders or time-of-day pricing that favor gas generation, cast long shadows across the financial risks associated with first-of-a-kind investments. These shadows magnify the significant risks arising from concerns about future international gas price levels and volatility discussed below. Third, China has the ability to manufacture and construct large-scale (300 and 600 MW) coal units, whereas it still imports CCGT technology. While foreign exchange is not an evident constraint on Chinese development, the higher costs associated with learning to produce Chinese gas turbines will influence gas power prices for some years. Fourth, gas power is unfamiliar to Chinese electricity sector professionals, who have a limited acquaintance with gas market economics. Again, experience in other countries in Asia and around the world indicates that anchor projects, usually initially financed or subsidized through public investments or favorable selective state policies, have been essential to the development of immature markets that demand firm, longer-term commitments to become commercially established.

While the particular prescription below of a package of public policies and private initiatives to develop deeper commercial gas markets, both in China and in the wider Asia-Pacific region, differs from that other analysts may put forward, there is substantial consensus that engineering a greater substitution of gas for coal presents a formidable challenge.[32] Yet the benefits to actors, governmental and commercial, in China and abroad, are equally impressive. CCGT power has lower unit investment costs and shorter lead times in construction than conventional coal. Gas plants have a smaller footprint on the land and require less cooling water. They offer greater modularity and lower economies of scale than coal facilities, making them a better fit for urban landscapes and more distributed generation. Gas-fired power outperforms coal in its energy conversion efficiency and lower non-CO_2 emissions profile. It is better suited for flexible load management and the operational safety of local grids. Especially in areas like Guangdong where small, sometimes oil-fired, generators, which may comprise as much as 45% of capacity, or in areas like Shanghai served by long-distance transmission from the West, gas can offer local support at the load center responding to the need for frequency adjustment or emergency response. Given the limited capacity for local hydro and pumped storage stations that are excellent peaking instruments, gas-fired power is the superior alternative for peak supply. [33] Moreover, in the light of its reduced scale, gas-fired generation is the preferred alternative if local, off-main grid networks are to be developed for captive supply in industrial zones, especially those with a need for exceptional power quality reliability for high-tech end users.

These several attributes of gas as an electricity source are particularly attractive for the fast-growing and wealthier Chinese southeastern coastal metropolitan areas. Higher income consumers in these more developed areas generally have increased demand for environmental quality. Air conditioning and appliance growth generally causes steeper peaks and the shifting sectoral composition of these areas has moved toward more advanced industrial and service production that cannot tolerate the frequency variations characteristic of many established Chinese grids. End-users tariffs in these zones are traditionally expensive and capable of financing incremental gas power capacity. Moreover, the prosperity and growth in the Southeast holds open the prospect of initial public subsidy to help meet the infrastructure costs of commercial market development.

In addition, two less transparent attributes of China's power system may make growing reliance on LNG-CCGT particularly attractive in seaports far from the coal producing Northwest. While mine-mouth coal prices administratively announced in national coal conferences appear to create a substantial price advantage for coal over gas, in recent years the levelized cost estimates for new coal plants with flue gas de-sulphurization and the all-in costs of LNG-fired electricity have had relatively close margins. Even without any adders for environmental quality and in the absence of time-of-day pricing that would improve the relative position of gas, when the delivered price of coal after transport approached the $70 international price (August 2004), LNG at US$4 to $4.50/mmbtu was quite competitive. If comparative analysis accounts for the fact that LNG is delivered under enforceable, long-term international contracts that are subject to arbitration and Chinese coal (or hydropower) remains subject to the vagaries and uncertain costs of domestic transportation monopolies and administrative prices decided far from their region, provincial authorities in coastal areas may decide that their quest to ensure firm energy supplies would enhance the priority given to gas. In such an analysis, the determinative factor in composing their growing energy portfolio will be how these authorities project the future of coal/gas price formation in China and the wider Asia-Pacific region.

The probabilities that a hypothetical shift of 50 GW of new coal power to gas could be induced depend on coordinated public, private and international actions that would directly advance the sustainable commercialization of gas markets in large and fast-growing regions of China.

If Chinese policy-makers, either at the national or provincial/regional level, were to perceive the relative developmental advantages of greater diversification of coal into gas, they would have to sponsor reforms to enhance downstream end-user gas markets complementary to gas power development, regulate tariffs and dispatch to reflect environmental quality and time-of-day rates, and contribute to the management of the one-time costs and risks of anchoring initial investments in gas infrastructure and off-take.

Similarly, private firms, both Chinese and multinational, whose asset values would increase with an explosion of the Chinese market for natural gas, would have to mobilize to support such investments. In such an effort, a key role may fall on international oil and gas providers with the financial capacity and experience to assume and manage higher risks across a broad portfolio of locations. This may be particularly true of investments – such as those in ocean and pipeline transport, LNG infrastructure and even power generation downstream of their traditional assets – that attend the development of new commercial markets in gas more vertically integrated than those familiar to classical fuel suppliers.

Third, a comprehensive deal to substitute more gas for coal in the mid-term growth of Chinese power would benefit from the commitment of national export-import banks and international financial institutions to offer more priority loans to infrastructure and other projects close to gas distribution and end use.

Finally, supportive financing could be enhanced by the redesign of climate change offset or aid mechanisms to monetize the environmental value of less polluting fuels, including natural gas. Given the relative scale of carbon mitigation ancillary to the hypothetical change in Chinese power markets we imagine, new instruments that subsidize a package of policy reforms and coordinated investments contributing to the programmatic development of expanded commercial gas markets is far more efficient than the international cooperation mechanisms now allowed under the Kyoto Protocol.

While direct actions in energy policy and investment are necessary elements in altering the development paths of China's power sector, they alone are unlikely to yield consequential results in the absence of complementary indirect changes in the context wherein gas markets function. Some contextual changes that would favor gas substitution could occur within the Chinese domestic sphere; others could be situated in the wider regional and international political economies. For example, if China were to pursue a general exchange rate policy of continuing currency appreciation, the price of imported gas would decline compared to that of local coal. Or, if China, for reasons unrelated to energy, were to follow a road of liberalizing its financial markets, the capital costs of CCGT, which are lower worldwide than those of coal installations, should again (after initial learning by Chinese equipment manufacturers) improve the relative value of gas-fired power.

Other actions by China that would establish a better context for gas development could be more associated with refraining from pushing ahead with actions that have not characterized the energy system so far. A portfolio of supportive inactions might include not reducing the effective price of national coal in the coastal metropoles. Gas may compete with coal on the central and eastern coast because coal's current delivered prices are inflated by rents extracted in its transportation from the interior. If coal price formation were freed administratively to move toward the opportunity costs of coal exported internationally, there would be a shift in rents from middlemen toward coal producers, but the current delivered costs to distant generators would remain substantially unchanged relative to gas. Again, the implicit decentralization of energy decisions that has prevailed during periods of high growth could be left in place by according more formal regulatory powers to provincial or other more local authorities. Sub-national regulators would retain the discretion to set pricing and competition policies best fitted to the differentiated load curves, reliability and environmental quality of the electricity portfolio locally demanded. Most critically, a national commitment (or, alternatively, an implicit or explicit delegation to sub-national authorities of the policy decision) to pursue energy security through diversity and strengthening of international markets that commodify fuel supplies, rather than through a (quixotic) quest for self-sufficiency, would seem a *sine qua non* for the thought experiment we postulate.

Shifts in the international context are additional necessary conditions that make such Chinese actions and inactions sensible and productive for presently improbable rates of gas market growth. First, prospective reliance by China on the secure evolution of gas commodity markets around regional and global LNG supplies can only be assured by international commitments and coordination similar to those that have been established in international oil markets under the auspices of the IEA since the mid-1980s. (Bohan, Toman and Wells 1996) Second, substantial investment in the expansion of available gas supplies and transportation infrastructure will be needed to bring gas prices and volatilities down to levels where gas is closely competitive with coal in the Asia-Pacific region. Current gas price formation in the Atlantic Basin remains tied to fuel oil or diesel in ways that, if extended globally, would make coal the predominant fuel of choice across the emerging markets. While there is substantial uncertainty about the prices at which new rounds of LNG contracting in Japan and elsewhere in Asia will settle, it appears clear that without large new investments in Middle Eastern fields like those in Qatar and Iran, currently uncommitted supplies of expected LNG production in the next decade are unlikely to be large enough to de-link gas from oil prices.[34] Without such de-linking, the prospects for displacing incremental coal combustion in China in the short to medium run, as well as its potential associated benefits for more sustainable development, will remain purely hypothetical.[35]

The substitution of 50 GW of gas-fired power for incremental coal-powered generation facilities is based on the recognition that development of new energy capacity will remain an overriding priority in Chinese policy. It also emphasizes that there are major options for this development that appeal variably to different provinces, agencies and business interests within China. Some of these development options would produce larger ancillary benefits to groups outside of China, including those focused on the mitigation of risks of climate change, whose interests could be mobilized to contribute to the costs of their preferred outcomes. The idea of development and climate deals, in which more climate-sustaining choices are made in emerging markets because they represent development alternatives with existing serious local support looks before and beyond the Clean Development Mechanism (CDM) by which the Kyoto Protocol seeks to engage the developing world. It looks before CDM because it makes no pretense of being a temporary stopgap for the assumption of mandatory targets by developing countries. It looks beyond CDM because it aims at immediate engagements in key emerging markets, whose greenhouse gas emissions are already growing at consequential rates, of far more ambitious scope than the project-specific definitions of climate additionality in the CDM.

Development and climate deals like that of the thought experiment contemplate mutual commitments to reforms in policy, investments in infrastructure and, where needed, changes in the wider political economic context in which alternative development options are sustainable.[36] Their objective is not to subsidize individual projects whose emissions are less than what business-as-usual might have produced, but to change the path of what is the usual business. In other words, development and climate deals shift energy baselines by establishing the conditions for continuing commercial markets that conform to established development priorities in their host countries. In this sense, successful cooperative deals must be close to the non-cooperative solutions that had a reasonable chance to have emerged because of local preferences in the absence of external influence – the type of solutions that usually form the foundation for effective international agreements. Development and climate deals like the increased rate of substitution of gas for coal power also do not require the elaborate structures and the intricate web of compensation payments to veto players that are typical of multilateral treaties. Instead, deals can be tailored to those public and private actors with the capacities and interests to play in the game. They demand no broad principles or general rules to create comprehensive new institutions, so much as pragmatic agreements that advance the specific economic goals of those who transact.[37]

Deals replace diplomats with line policy makers and firms in the sector, enhancing the likelihood of realistic analysis and proposals. They focus, for better and worse, on the contextual conditions in which commercial markets can flourish without dependence on long-term subsidies. Finally, like the case of Chinese gas, development and climate deals acknowledge that in emerging nations or economies in transition, there is no such thing as business-as-usual against which to measure the value of change. To be in transition is to be in the process of determining the institutional and policy reforms that set the baseline of everyday commercial practice. Deals, in effect, negotiate the energy baseline in the mutual commitments being made to interactive policy, investment and context. Amidst other actions that might be imagined to serve the twin goals of economic development and climate sustainability, a portfolio of deals like Chinese gas would offer a contribution whose feasibility merits serious consideration.

[1] Much of the material in this first sections of this paper draws upon Chi Zhang and Thomas C. Heller, Reform of the Chinese Electric Power Market: Economics and Institutions, in *The Political Economy of Power Sector Reform: Experiences in Five Major Emerging Countries* (forthcoming, Cambridge University Press 2006)

[2] Statistics have been collected from a variety of different English and Chinese language sources. The most official and reliable sources, principally from the China Energy year book, the U.S. Department of Energy's Energy Information Administration's (EIA) International Energy Outlook and the OECD's International Energy Agency's World Energy Outlook (IEA), lag several years behind. Consequently, much of the reliable data reported by the sources in their most recent publications in 2004 reflects the situation in China in only 2003 or 2002. Moreover, different sources emphasize different measures of energy development, including total primary energy

used, end use energy consumed and installed capacity. These statistical differences will be noted in the paper, but are frequently difficult to reconcile. More recent estimates of the power sector profile are more speculative, often based on planning expectations that rarely prove accurate or on officially recorded projects in a context where all authorities agree that approvals systematically trail construction on the ground. For the purposes of this paper, we will use reliable and official figures to compile graphic representations, but will cite more speculative estimates to give a more current sense of the scale and speed of growth.

[3] Remarks of Zhang Guobao, vice-chairman of the National Development and Reform Commission (NDRC), reported in China Daily, http://www.chinadaily.com.cn/china/2006-06/09/content_612424.htm

[4] "China's total power installed capacity reaches 531 Gigawatts", 2006-06-07 Xinhua News Agency, http://englishsina.com/business/1/2006/0607/80039.html

[5] Jiang Kejun, Hu Xiulun, Energy Demand and Emissions in 2030 in China: Scenarios and Policy Options (preliminary manuscript in preparation 2006); see section three (model assumptions and scenario definition)

[6] Estimates by the NDRC reported on June 8, 2006 at http://news.yahoo.com/s/afp/20060608/bs_wl_afp/china energyelectricity

[7] Extraordinary improvements in energy intensity in this period coincided with the rationalization of retail tariffs resulting in higher power prices, sectoral shifts from manufacturing to services, and de-emphasis of policies favoring state-owned enterprises in energy intensive heavy industries. The one-time character of these shifts may account for the recent return to historically more typical levels of energy intensity in fast growing economies.

[8] Jiang and Hu, (forthcoming 2006), section 4 (results)

[9] The projection for 2003 to 2005 is based on a 7%growth rate to reach the government 10th Five-year plan target, which was revised upward in March 2003. A 5% growth rate is assumed for the second half of the decade.

[10] The failure of the first large hydropower project in the 1950s, San Men Xia Hydro Station, and the withdrawal of Soviet technical assistance in 1960 also adversely affected hydropower development.

[11] China's exploitable hydropower resources are estimated at 378.5 GW. (Fridley 2001).

[12] Numbers for 2005 were calculated on the basis of government planned development, but already, as noted above, lag behind actual construction and underestimate coal-fired capacity.

[13] EIA, International Energy Outlook 2004 at 123.

[14] Chen (2005) at 2

[15] EIA (2004) at 124.

[16] Jiang and Hu (forthcoming 2006) in section 4 (results). These policies assume the extension and implementation of the ambitious targets for energy conservation recently announced in Beijing, including the cutting of the average amount of energy needed to produce each good and service by 20% in the next five years.

[17] EIA International Energy Outlook 2004 estimates coal will remain the dominant fuel for electric power supply, with a projected 72% share for total energy use for electric power in 2025, compared with 76% in 2001 (p123). Similarly, the IEA World Energy Outlook 2004 estimates that coal's share will decline from 77% of kilowatt hours generated in 2002 to 72% in 2030 (p220). Please note that the EIA and IEA statistics cited in the text and in figure 4 represent actual energy generated consumed; these differ from those in figure 3, which graph capacity fuel structure.

[18] Jiang and Hu (forthcoming 2006), section 1 (background)

[19] Note that Chinese sectoral statistics may have been distorted in past years by the possible attribution to industrial consumption of residential and other power usage by workers employed in state-owned enterprises (*danwei*), who received housing and transport and other personal services directly from the enterprise. This potential distortion is now declining due to the separation of these from the economic unit.

[20] See DRC (2002) Chapter 3 for the source of literature. See also McElroy (1997), World Bank (1997).

[21] Calculations based on data provided by the EIA, July 2005 in Report #DOE/EIA-0484 (2005) available at http:www.eia.doe.gov/oiaf/ieo/pdf/ieoreftab_10.pdf.

[22] China's Air Pollution Control Law was promulgated in 1987. It has since been amended several times to tighten the control. The Electric Power Law of 1995 also provided for environmental protection in electricity development.

[23] Remarks of Zhang Guobao, vice-chairman of the National Development and Reform Commission (NDRC), reported in China Daily, http://www.chinadaily.com.cn/china/2006-06/09/content_612424.htm

[24] Recent empirical studies indicate that many results of the Chinese reform efforts are characteristic of other large emerging economies. Electricity sector reforms in Western, mature, slower growing power systems were motivated by efficiency considerations aimed at cost-reductions. In faster growing developing countries like China or India, the driving concern was attracting new capital for infrastructure expansion in financial systems that had reached the limits of state banks to supply additional resources. While China's reform history has particular features that distinguish it from other major emerging markets, it shares with them a record of incomplete transition in which political resistance to change was expectable because declining average system costs were never realistic possibilities for incremental capacity additions. Heller & Victor (forthcoming 2006), introduction and conclusions.

[25] The Province of Guangdong is one exception. While its assets belong to the State Council, the provincial government and its power company were granted operating controls of the assets since the early days of reform and have been operating the system independent of SPC.

[26] Heller & Victor (forthcoming 2006), Conclusions.

[27] In fact, government planning is such an entrenched fixture in the Chinese economy that even reform experts believe that pricing, project design and financing should continue to be authorized by the NDPC to maintain stability, and the function of the regulatory commission should mainly be designing rules of the game, and supervising the implementation of NDPC authorized projects. See, for example, International Financial News, October 28, 2002.

[28] Liu Jipeng, China Economic Daily, September 16, 2002.

[29] Actual EU emissions reductions required of the EU may, of course, be considerably larger depending on economic growth and other factors that can expand emissions over the 1990 base. Alternatively, 213 million tons of CO_2 reductions are more than twice as large as the total emissions reductions from the 100 largest Clean Development Mechanism (CDM) projects in the development pipeline in 2005. Jackson, Joy, Heller & Victor, Greenhouse Gas Implications in Large Scale Infrastructure Investments in Developing Countries: Examples from India and China (2006).

[30] Chen (2005) at 3. This planned increase would give gas-fired power an approximate 6% share of the nation's expected installed capacity in 2020.

[31] Petroleum Intelligence Weekly (June 12, 2006 at 5) lists approval for China National Offshore Oil Company's (CNOOC) terminal at Shenzhen, Fujian, Shanghai, Zhejiang and Jiangsu; Petrochina's planned terminal at Dalian; and Sinopec's proposed terminal in Shandong.

[32] The International Energy Agency in 2002 listed five key challenges that would have to be solved before China's gas markets could become commercial. These included: (1) effective and timely development of a downstream gas market to support investment in gas infrastructure; (2) improving the financial health and capabilities of local distribution networks to expand and switch from manufactured to natural gas; (3) reforming gas pricing policies to facilitate end use markets and overcome first-of-a-kind costs; (4) introducing competition in stages to allow early investment protection while initial costs decline; (5) defining a national gas/energy policy that clarifies the relative priorities accorded to competing fuels. (IEA 2002).

[33] See Chen (2005) at 10. Such hydro stations are insufficient in number and new sites are hard to find. Small diesel (oil) units, on which China has relied for peak power, are expensive per kilowatt hour, poor in efficiency and high in pollution. The capacity of coal-fired stations far from demand centers to meet peaking needs is contested.

[34] Whether Asia-Pacific and/or global prices for natural gas will de-link from oil is fundamentally a commercial question, but one that is subject to a variety of corporate and national strategic decisions about optimal market development. Summer 2006 LNG prices in the Atlantic market hover near $7/MMBtu. New costs for East-West pipeline gas for industrial users have been raised to around $5/MMBtu. And it is widely felt that the $3/MMBtu price for the initial CNOOC 3.7 million ton/yr. LNG terminal at Shenzhen, with indexation reportedly capped at an oil price of $25/bbl., is likely a one-off, first-of-a-kind deal. Negotiations now continue over prices for CNOOC's Fujian 2.6 million ton/yr. terminal, with debate both over prices and indexation caps. Yet, interest in Chinese LNG remains strong among major sellers (see Petroleum Intelligence Weekly, June 12, 2006 at 5) and there are large reservoirs of stranded gas in

Siberia, the Middle East and Southeast Asia-Australia that could be profitably developed for prices in the $4-5 dollar range that would make gas a competitive fuel in the wealthiest Chinese provinces. It is precisely because opinions among gas professionals differ on whether the industry will move commercially toward price de-linking that the opportunity for political deals to influence market development paths is of interest.

35 The longer-term future of sustainable energy development in China (and India), like that of the United States, ultimately depends on clean coal technologies with sequestration. The value of a gas for coal substitution program is the shorter- to mid-range displacement of some sub- or super-critical new coal-fired generation in the interim before clean coal with sequestration can be developed, commercialized and diffused.

36 For earlier and more general discussion of the concept of Development and Climate deals, see Heller & Shukla (2003).

37 The concept of separate deals with major emerging markets raises questions familiar to international economics and international relations theory. Trade economists suggest that minilateral or regional trade deals are generally inferior to multilateral institutions. This conclusion assumes a multilateral agreement is politically practical in a way that belies much of the history of both WTO and regional trade blocs. The WTO has been a slow-evolving regime, while most intense trade integration in the past half century has been among regional players following a strategy of agreement among core nations with shared values and interests, followed by expanding accession on terms dictated by the core at the regional peripheries. Yet, the net result of this process of minilaterally-centered regime building has not clearly deterred growth of the WTO multilateral system so far. The stalled progress in the negotiation of the Kyoto Protocol, especially with respect to eliciting mitigation commitments from the United States and all major emerging mar-

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"Common but differentiated responsibilities": behind this vague term, the Kyoto Protocol means to compel developed countries to make the greatest efforts in combating climate change, while encouraging emission reduction policies in developing countries. But the main tool of its implementation, the Clean Development Mechanism, is not sufficient to fuel the structural action needed in the South. Creating this momentum, which lies at the heart of sustainable development, is one of the major challenges facing climate negotiations.

From Rio to Marrakech: Development in climate negotiations

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The creation of a global regime for reducing greenhouse gas (GHG) emissions is dependent on reaching an agreement on the role of developing countries. However, although the Rio convention – the cornerstone of international climate negotiations – laid down the principle of "common but differentiated responsibilities", this rapidly became the object of differing interpretations. While Brazil wished to determine countries' commitments on the basis of their historical responsibility since the industrial revolution, the Indian Anil Agarwal proposed an egalitarian allocation of emission allowances for all the inhabitants of the world. The United States, stressing the need for global action, indicated the unacceptable risk to the American economy of a unilateral commitment by developed countries. The international climate commitments regime must reconcile the interests of all parties and, above all, assist Southern countries in achieving sustainable development.

Financial agreements and mechanisms

How can developing countries (DCs) contribute to the fight against climate change through domestic GHG emission reduction policies under international climate agreements? During the Kyoto conference, DCs declined to make any quantified or binding commitments for the first commitment period (Box 1). But even before the conference, the United States had made it known that it could not commit to reducing its GHG emissions without a similar commitment from DCs[a]. And by the close of the Third Conference of the Parties (COP3), it was clear that this exemption for DCs was only provisional, and that the negotiation of future commitments would only be possible if the issue of their participation was addressed. The years following Kyoto were in fact marked, in both the North and the South, by a number of initiatives aimed at developing suitable methods for integrating DCs into the Kyoto model: differentiated allocation systems as a means of distributing emission allowances according to often irreconcilable rules of equity; non-binding commitment schemes; or even multi-stage approaches, with progressive and differentiated participation according to the level of development reached in the countries concerned.

Since then the negotiating climate has seen considerable developments. *The withdrawal of the United States has weakened the political weight of the Protocol and created an imbalance in the conditions for its implementation.* The United States, which was nevertheless at the origin of the Protocol's key concept of quantified commitments coupled with an international emissions trading system (which Europe came over to reluctantly), is now criticizing the inadequacy of short-term action on emissions, which would harm economic momentum without achieving the environmental efficiency sought. It proposes action "based on science" that "encourages technological innovation". This model appeals: in June 2005 the United States signed the Asia-Pacific Partnership agreement with Australia, Japan, China, India and Korea, thus covering 50% of global GHG emissions. The agreement rules out any form of binding commitment and focuses on technological cooperation and private sector involvement. Although several ASEAN countries, Canada and Mexico have since shown their interest in this approach, the partnership has been widely criticized not only by the European Union and major environmental organizations, which condemn its worthlessness given the absence of any target outcome, but also within the United States itself where the Republican Senator John McCain described it as “nothing more than a nice little public relations ploy”.

This venture in which innovation and technology transfer would make it possible to control emissions without questioning the energy paradigm, is attractive, especially for emerging countries. Its success, and the danger it represents as an alternative to the international coordination model, have successfully revealed the weakness of the discourse and the prolonged absence of action by supporters of the Kyoto Protocol on this issue. Today, Europe is fleshing out its domestic research and development strategy and is in turn striving to build a dialogue on energy policies and technological cooperation with the major emerging countries. But for Europe and its partners that supported the position of DCs in Kyoto, the priority for dialogue on future initiatives (post-2012) instigated in Montreal is to ensure more active participation, at least for middle-income countries.

Reconciling development and emission reductions

Beyond negotiation postures and rhetorical speeches on responsibility and equity, the reluctance of DCs to commit further is based on a legitimate concern: limiting the growth in emissions – which are currently very low given the low level of energy consumption – could restrict their access to energy, and thereby threaten their development. In the absence of an explicit vision of the future emissions trajectories that an international regime could impose on Southern countries, *some feared ratifying a ‘de facto’ division with this agreement*, where developed countries today represent half of all emissions for only a sixth of the population. These ideas have been refined since: projections generated by modeling exercises to meet the objective of stabilizing GHG concentrations in the atmosphere describe medium-term growth in emissions for DCs. In order to limit climate change to reasonable levels, middle-income countries must return to their 1990 level of emissions by 2050, while the others could double or even triple this baseline level. At the same time, a fourfold reduction in developed countries’ emissions is required[1] (Figure 1).

In this way, an ambitious target for GHG concentration stabilization can be pursued by granting the different regions of the world varying development margins that are adapted to suit their initial situations. However, achieving such targets depends on short-term control of growth in emissions in DCs. Two arguments are nevertheless put forward to postpone such action:

1. *Environmental action is a luxury that only rich countries can afford*, and DCs would only have the means to control their emissions once they reach a development level comparable to that of Northern countries. This argument is based on an ‘end-of-pipe’ approach to environmental policies, and is valid for certain issues (catalytic converters, sulfur capture in power plants, etc.), but not for climate change: developed countries in fact have the highest emission rates in relation to their population because of their energy-greedy economic model. Above all, it underestimates a major economic opportunity: in DCs, the energy, industrial and urban infrastructure that will

Box 1

From alarm to international agreements

The United Nations Framework Convention on Climate Change

The climate change alarm raised by the scientific community was gradually echoed by the international authorities, leading to the United Nations Framework Convention on Climate Change (UNFCCC), which was opened for signature by States in 1992, during the Rio Summit on environment and development. This Convention sets the objective of stabilizing “greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”, while ensuring that such a level is “achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner” (article 2). To accomplish this, the parties to the Convention are requested to act “for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof” (article 3).

The Kyoto Protocol

After the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 1995) declared that the commitments made under the Convention were insufficient to prevent the negative effects of human activities on the climate, the party States decided to negotiate a protocol with a view to consolidating the Convention. Adopted in December 1997, the Kyoto Protocol includes *binding provisions* according to which by 2012, *industrialized countries must reduce their emissions of six GHGs by at least 5%*. *Developing countries* have no emissions targets under the Protocol, but are involved in the international effort *through voluntary initiatives* and especially an ad hoc system, the Clean Development Mechanism (CDM).

The Marrakech Accords

The rules specifying the arrangements for implementing the Kyoto Protocol were drawn up during the Seventh Conference of the Parties and are known as the Marrakech Accords. These agreements set out the means of calculating emissions and their reduction, the rules for integrating carbon sinks into reduction targets, the way in which the observance system works and its goals, and the rules and eligibility criteria for the Protocol’s flexibility mechanisms. The Marrakech Accords also provide for the creation of financial and technical assistance to DCs.

determine their energy consumption in the decades to come has not yet been built.

2. *The fear that any investment* aimed at reducing emissions *enters into competition with the financial requirements needed to sustain the development process*. This argument is clearly justified for certain measures, such as CO_2 sequestration, which mobilizes capital by doubling investment costs. But where urban planning, transport and energy efficiency are concerned, a wide range of initiatives exist that are climate-friendly and also sustain the development process. The resurgence of concerns about the security of energy supply provides another important opportunity for synergy with climate policies.

At first highly focused on 'top-down' approaches dealing with the costs of implementing climate policies and the potential benefits of market mechanisms, academic research and informal negotiations now have a far greater understanding of the operational content of these policies and the conditions of their application. Paradoxically, by revealing the wide range of initiatives required, sectors of the economy affected, technologies to be put into use and levels of decision-making concerned, this corpus also weakens the argument of the Asia-Pacific agreement, based on the support of a limited number of key technologies. It also endorses the supporters of an international coordination regime, which is the only kind capable of providing a sufficiently predictable signal for economic agents and supporting the emergence of solid domestic policies and private initiatives. But in the dialogue phase that has begun in preparation for the post-2012 period, two factors will also play a decisive role in the ability of parties to the Kyoto Protocol to convince their partners: the outcome of policies implemented by these countries in order to meet their commitments; and the assessment of participation mechanisms the Convention and the Kyoto Protocol currently offer to DCs.

Fig. 1 **Scenarios for 2050 emissions targets**

Stabilization target for CO_2 concentrations	Temperature increase (IPCC average 2001)	Targets for 2050 compared to 1990 emissions	
		Developed and transition countries (Annex I)	**Developing countries (non-Annex I)**
550 ppm	+2.5°C compared to the pre-industrial era +1.9°C since 1990	A **factor 2** reduction	**x 2** (Lat. America, Middle East, South East Asia) **x 5** (Africa, South Asia: no effort)
450 ppm	+1.6°C compared to the pre-industrial era +1.0°C since 1990	A **factor 4** reduction	**x 1** (Lat. America, Middle East, South East Asia) **x 3** (Africa, South Asia: no effort)

Source: LEPII-EPE, 2003.

Tools for combating climate change in developing countries

Important financial mechanisms, whether specific to the Climate Convention and the Kyoto Protocol, or broader in scope, play a part in financing the fight against climate change in DCs (Box 2). The Global Environment Facility (GEF) created in 1992 has certainly contributed to the emergence of interesting projects in terms of energy efficiency and renewable energies, and has encouraged training in these fields in host countries. However, it has focused on initiatives with high environmental content, which are often out of touch with real development dynamics. This approach has been further consolidated by the recent adoption of a system for allocating aid according to the contribution of beneficiary countries to the global environment – to the detriment of the 'development' approach, even if part of the contributions donors make to the GEF can be counted as official development assistance (ODA). On the other hand, DCs are reluctant to commit to reforming their national or sectoral policies, arguing that insufficient resources would be available to assist them.

While making the GEF the operational multilateral financial instrument of the Convention, the Marrakech Accords ratified the creation of several funds resulting from compromises reached during negotiations. *These instruments*, which are not yet fully operational, *mobilize scant resources*, and in fact represent little in view of the overlapping challenges for energy and the climate in Southern countries. Furthermore, they are not directed at the energy sector, with the exception of the "adaptation" and "capacity-building" elements of the Special Climate Change Fund (SCCF). All things considered, these funds are not therefore expected to play a significant role in the energy sector – even though technology transfer is one of the objectives of the SCCF – owing especially to donor countries' lack of enthusiasm for this fund.

Although the Marrakech Accords put no specific figures to commitments, a series of developed countries agreed under the Bonn Declaration to increase their financial efforts. Despite its lack of success in mobilizing resources for the funds it created, the Convention has on the other hand clearly won the battle of ideas: all international funding agencies have acknowledged the importance of the issue of the fight against the greenhouse effect and its connection with development assistance. Today, initiatives aimed at reducing GHG emissions in the energy sector represent far greater amounts than those of the Convention's specific funds. This aspect is, however, neglected or even completely ignored in international negotiations, especially due to the fact that DCs are endeavoring to demand 'additional' financing to ODA and are wary of the rhetoric of donors, who urge them to integrate 'climate' activities into their development strategy.

The Clean Development Mechanism

The principle of the agreement reached in Kyoto can be summed up in two terms: quantified commitments and flexibility mechanisms. In the first stage, *developed countries* make a commitment, for a given period (2008-2012), to *keep their GHG emissions* below an established threshold. These countries, known as Annex B countries (the part of the Protocol that sets these limits), consequently have quotas (or emission allowances) corresponding to their commitment. In the second stage, in recognition of the global nature of the greenhouse effect and in the context of the joint implementation of action, *a country that keeps its emissions below its quota may sell its surplus of quotas* to a country whose emissions are too high: this carbon market should make it possible to create a price signal and to reduce the total cost of climate policies by encouraging the least expensive reduction initiatives, regardless of their location. This mechanism is accompanied by two 'project-based mechanisms': JI (Joint Implementation) for Annex B countries and the CDM (Clean Development Mechanism) for DCs. In both cases, investment made in a host country leading to a reduction in GHG emissions in comparison with a baseline level generates carbon credits[b] that Annex B countries (or private entities in these countries) may acquire in order to increase their emission quota and thereby meet their own commitments.

Article 12, which defines the CDM, gives it two objectives: contributing to sustainable development in host countries (DCs) and helping Annex B countries to meet their Kyoto commitments. The CDM, which appeared in the 'final package' on the very last night in Kyoto, contains the ambiguity that made it possible to reconcile hitherto irreducible positions. The Americans and their partners are convinced that DCs host significant opportunities for low-cost emission reductions. DCs see this as an opportunity for additional resources to ODA to finance quality development projects and encourage technology transfer[c]. But many fear seeing developed countries using this as a means of meeting their commitments at low cost, without making the necessary changes at home, especially in terms of energy. DCs also fear selling off their most attractive reduction opportunities and thereby increasing the cost of their future commitments.

Environmentalist circles and NGOs are also divided over the issue of the CDM. It is firstly feared that the sustainable development focus of projects, which is left to the judgment of host countries (but could it be otherwise?), may direct the CDM towards the 'lowest bidder' in environmental or social terms. Some are especially concerned about the environmental integrity of the Protocol: the CDM does not create additional emission reductions, but moves emission reductions to developing countries in exchange for carbon credits that increase the emission quotas agreed in Kyoto for Annex B countries. To avoid the Kyoto agreement losing its effectiveness if these new credits do not correspond to real reductions, the validation of CDM projects depends on an additionality criteria aimed at guaranteeing that credits reward real emission reductions, in relation to a baseline where the projects had not been implemented.

Despite these initial doubts, today everybody is playing the game. Private investors rapidly showed their interest in this mechanism. Some DCs that were long highly reluctant, such as India, have now

Fig. 1

Financial mechanisms in the fight against climate change

The *Global Environment Facility (GEF)*. Even before the Rio summit, donor countries had agreed to create a financial fund dedicated to the major global environmental concerns (the greenhouse effect, biodiversity, the ozone and international waters). In 1992 the GEF became the financial mechanism of the Climate Convention, mobilizing almost five billion dollars in 10 years, all fields taken together. Managed by the World Bank and implemented by this organization, along with the United Nations Environment Programme (UNEP) and its Development Programme (UNDP), the GEF suffers from excessive red tape and a limited budget, meaning it is not able to play a quantitatively significant role, but instead backs exemplary and reproducible technical or institutional innovations.

The Marrakech Accords endorsed the creation of three funds: the *Special Climate Change Fund (SCCF)*, the *Least Developed Countries Fund* under the aegis of the Climate Convention and the *Adaptation Fund* under the Kyoto Protocol. The first is the result of a compromise between the European Union and oil-producing countries, concerning the effects on their economies of loss of revenue caused by the projected decrease in fossil fuel consumption in developed countries. The second constitutes a response to the fears of DCs, especially least developed countries (LDCs) concerning the fact that the GEF does not apply to activities concerning adaptation to climate change. The third, based on a more equitable redistribution of levies on CDM carbon credits (share of proceeds), may be seen as compensation for accepting market mechanisms. In total, these three funds currently represent less than 200 million dollars per year.

In addition to these specific funds, the fight against climate change in DCs is also financed by classical ODA sources. In the *Bonn Declaration*, the European Union, Canada, Iceland, New Zealand, Norway and Switzerland committed themselves – while urging other developed countries to do likewise – to providing additional financial support to DCs of up to 450 million dollars per year from 2005 onwards (compared to 2001). This commitment includes contributions to the GEF and to the Marrakech funds, as well as additional bilateral funding for projects connected to climate change. *All the various international, multilateral or bilateral financial institutions have considerably developed energy efficiency and renewable energy projects.* Thus, in April 2006, the World Bank presented its Investment Framework on Clean Energy, aimed at backing this kind of project, to which it committed 750 million dollars in 2005. In France, the French Development Agency (AFD) made energy intensity reduction its core area of activity in emerging countries.

developed their capacities for proposing and assessing projects. Several Annex B countries have declared their intention to purchase, and bilateral and multilateral purchase funds have been set up. In November 2004, the European Union decided to authorize the importation of CDM credits in the industrial emission trading system (EU-ETS) it created. Finally, NGOs have set up monitoring networks, quality labels (the WWF Gold Standard) and are involved in projects with high development content.

By the end of March 2006, only 4 million tons of CO_2 ($MtCO_2$) of credits had actually been emitted. This figure is nevertheless revealing. The 740 potential CDM projects registered in mid-2006 represent around 200 $MtCO_2$ of credits per year[d], a figure that should not increase much for this first Kyoto period. Volume projections for the carbon market indicate an annual demand of 200 to 640 $MtCO_2$ of credits for the CDM for the 2008-2012 period, estimations that were reduced following the non-participation of the United States[e] and the resulting abundance of quotas for transition countries (known as the 'hot air[f]' effect).

The evolution of the market beyond this point will depend on the outcome of discussions on future commitment periods, which will condition the value of credits after 2012. This price currently remains low, at around 10 dollars per ton of CO_2. This limits the appeal of the mechanism, since in addition to transaction costs that cannot be reduced, projects must deal with the costs inherent in the learning and start-up phase of such a mechanism.

The CDM, a tool for sustainable development?

In view of the conditions in which the mechanism was created, the reality of its dual objective in the effective implementation of projects may be questioned. Is it not simply a rhetorical figure? In theory, the appeal of the mechanism is that it makes it possible for the goal of reducing emissions in Northern countries to contribute to the sustainable development of DCs.

The *first argument* is that the CDM creates a price signal that any private entrepreneur may take advantage of: it thus constitutes an incentive for foreign investors to increase their level of action in DCs and to transfer the most modern technologies to these countries. The *second argument* is that carbon value may sometimes merely give an environmental tinge to an investor's initial project (with a limited impact on the local area), but may also, in certain cases, improve the overall economic results of the investment project. In this virtuous case, the CDM would act as a means of consolidating the financing of the development project itself. For example, when a service company takes over the exploitation of a concession (urban heating, electricity, public transport) in a DC, this often implies modernizing equipment in order to guarantee medium-term profitability. Improving the energy efficiency of equipment is thus a central part of the takeover project. The contribution of the CDM to the financial balance sheet increases the chances of the project being carried out, thereby making it possible to improve the service (development) and reduce emissions (environment).

In this first phase, analyzing the real impact of the CDM in terms of development implies distinguishing two legitimate issues, which if merged into one, may lead to unsuitable conclusions: it is essential to not only assess the contribution of activities covered by the CDM to the sustainable development of DCs and to combating the greenhouse effect, but also the ability of the CDM to cover all the elements of development that must be transformed as part of the fight against the greenhouse effect. Next, when examining the current portfolio and the development of proposals for future regulations, it is important to make a distinction between the fundamental qualities and limits of a market mechanism and those specific to the CDM institutional agreement. From this perspective, the performance of the CDM in terms of sustainable development is based on three parameters: the macroeconomic influence of the mechanism on host countries; the geographical distribution of projects; and the sectoral breakdown of projects implemented.

The macroeconomic influence of the CDM

The projects currently declared to the CDM executive board correspond to a total amount of projected credits by 2012 of around 835 $MtCO_2$[2]. The estimated amount of associated financial transfers is therefore 10 billion euros accumulated since 2000. These figures are low compared to those for foreign direct investment (FDI) in DCs – which exceeds 175 billion dollars per year – including FDI to the African continent alone, which receives on average 16 billion dollars per year (of which 11 billion go to sub-Saharan Africa, excluding South Africa). They are also low in comparison with flows of official development assistance, on average 27 billion dollars per year for low-income countries alone[3]. The CDM can therefore only marginally influence development dynamics in DCs: expectations concerning the CDM must be put into perspective, especially as regards the second objective of contributing to sustainable development in host countries.

The CDM may nevertheless play a role in investment in the infrastructure that conditions the future emissions of DCs. In the 1990s, FDI in infrastructure reached on average 70 billion dollars per year, accompanied by 13 billion per year of official development assistance (ODA)[4]. The geographical distribution of these sums is highly varied: 123 countries share 30% of FDI while five countries alone receive 50%. In sub-Saharan Africa, over the same period, the amount of private capital was slightly lower than the amount of

ODA invested in infrastructure, reaching around 2 billion euros per year. On this scale, the CDM could theoretically have a considerable impact on the dynamics of infrastructure investment. This would nevertheless imply moving beyond certain limits of the mechanism that act as a brake on both the development of the CDM in Africa and its use in infrastructure.

Africa shunned by the CDM

Of the first 165 projects validated and registered by the CDM executive board, only four were situated in Africa, compared to 61 in Asia and Oceania and 96 in Latin America and the Caribbean[5]. Furthermore, they concern two countries that are not representative of the rest of the continent: South Africa and Morocco. Of all the projects in the CDM institutional pipelines (around 650), only 2% represent sub-Saharan Africa (4% of credits), with 0.3% situated in Nigeria[g] and 1% in South Africa (3% and 1% of credits respectively). The heart of the African continent therefore seems to have been largely forgotten by the CDM (Figure 2).

Several factors are to blame, the first of which is the lack of institutional capacities. The acceptance of CDM projects and their development cycle imply administrative procedures and prerequisites (such as the appointment of a designated national authority as the interlocutor for project developers) that have been established with varying degrees of efficiency depending on the country. Specific efforts to strengthen CDM capacities have been undertaken by international funding agencies or NGOs where their weakness presents an obstacle to the development of these projects. But only an active CDM development policy in host countries (identifying potential projects, awareness campaigns among local economic actors, etc.) can give the mechanism significant momentum. In this respect, India is a perfect example: its strong CDM development policy has enabled the country to host 39% of CDM projects declared to the executive board[6], including a significant share of energy efficiency projects, which are among the most beneficial projects for the host country in terms of sustainable development.

However, there is no guarantee that such an approach is sufficient to stimulate CDM projects in Africa, and more specifically in LDCs. The mechanism's ability to consolidate private investment dynamics falls short in countries that receive only a limited flow of such investment. The African continent receives only 2.5% of world FDI, with 1.8% going to South Africa alone.

It is also evident that Africa's share in the CDM is comparable to that of its emissions: Africa produces 3% of global combustion-related CO_2, with South Africa accounting for over 40% of the total for the continent. Conversely, the 'first places' in the CDM, held by China, Brazil, India and South Korea, reflect the level of economic and investment dynamism in these countries, but also the fact that they are the four largest GHG emitters outside Northern countries. If the CDM is being significantly developed in China, despite the fact that the administrative framework there is not the most favorable[h], this is because the 'country risk' associated with investment is far lower in China than in the great majority of other DCs, where the impact of the 'country risk' on the return on investment is often higher than the benefits provided by the CDM.

This observation applies to all LDCs: the fact that the CDM is of such significance to private project developers makes it unsuited to the situation of these countries, where investment remains largely a public initiative (States, development agencies, etc.). In this respect, the CDM creates unreasonable expectations, which should be clarified by the dialogue on post-2012 international climate action. But the originality of the mechanism, based on the idea that project developers adopt it in order to complement, redirect or accelerate their investment in relation to the climate issue, must be preserved. The 'decentralized efficiency' of the CDM is where its strength lies, but also its difficulty in meeting the needs of LDCs.

It is therefore essential to refute abstract approaches to the mechanism, seen as a lifeline for sustainable development in LDCs, and the highly misleading associated proposals, such as those for administrative quotas per region for the CDM. On the other hand, the link between the CDM and ODA merits a fresh appraisal that moves away from the fears (shared by both the North and the South, although for different reasons) that the CDM will divert ODA, and, on the contrary, considers the possibility that the two mechanisms may be mutually beneficial.

Is the CDM absent from infrastructure investment?

Analysis of the first 175 projects registered by the CDM executive board reveals a predominance of renewable energy activities, especially biomass (40.5% of projects), hydroelectricity (21.7%) and wind power (8%), as well as a considerable number of methane recovery projects (15.4%). However, the picture is very different when looking at the volume of emissions reductions generated: projects for reducing industrial gas emissions represent almost three quarters of carbon credits expected[i], to which are added the 14.2% of credits from landfill methane capture projects. The share for biomass falls to 6%, with all other renewable energy projects representing less than 6% and energy efficiency projects less than 1% (Figure 2).

For this first period, 85% of the financial impact of the CDM is thus concentrated on a small number of projects that make no contribution to local development, or even to local environmental concerns. Conversely, energy efficiency and renewable energy projects, whose local economic and social repercussions are indisputable, receive only 18% of CDM revenue.

Many observers criticize the crowding out effect on other components of the CDM activity portfolio due to the appeal of projects concerning industrial gases. But in the absence of investment in these attractive projects, would there really be a significant increase in projects with high development content? It seems unlikely. In the first place, the supply of CDM credits is currently estimated at around 50 $MtCO_2$ equivalent, or approximately a quarter of the estimated demand according to the most pessimistic projections. There is not really, therefore, a case of supply saturation by major industrial projects. Although low, the price of credits on the carbon market is sufficient to have considerable appeal in areas such as biomass, wind power or small hydropower. Projects in these sectors are nevertheless of small unit size, meaning 3 000 to 12 000 projects of similar size would need to be validated by 2008 for the CDM to supply the estimated demand of Annex B countries: this is not realistic.

The success of large industrial projects is down to their favorable characteristics in terms of opportunities provided by the carbon market for Northern actors. Although the CDM has created a useful windfall effect, stimulating and simplifying these projects, the pool of projects likely to be implemented in the future is limited: total HFC, PFC and SF_6 emissions represent only 1% of global GHG emissions, and diffuse landfill methane emissions around 2%. This does not however solve the difficulties inherent in activities concerning energy efficiency improvement and the development of renewable energies. These projects require the involvement of local actors capable of guaranteeing the development and implementation of projects on the ground. Their large-scale circulation comes up against the characteristic difficulties of development projects, where institutional capacities (public and private) are often more limiting factors than financial capacities.

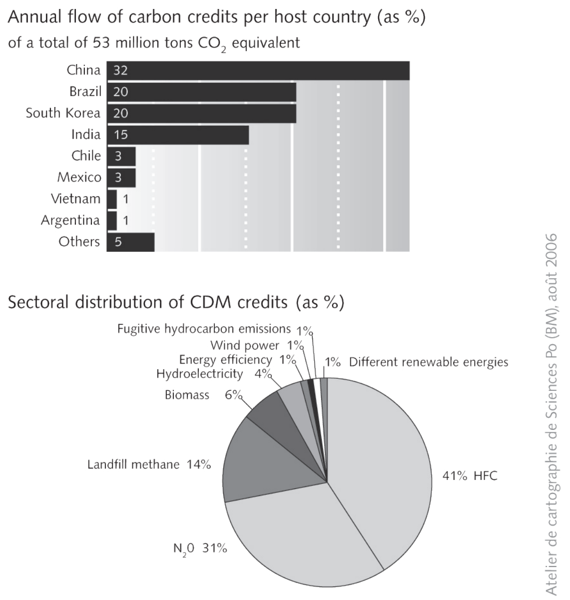
This unilateral CDM model, requested by numerous countries at the Hague conference, is nevertheless the best hope of ensuring activities are developed that efficiently associate local development dynamics with impacts on GHG emissions. This kind of project, developed and managed by local actors in the host country without any input from Northern investors, already represents a growing share of the portfolio of countries such as India and Brazil. The emergence of projects with high development content is therefore largely dependent on the ability of DCs to draw up public policies that encourage the development of private domestic projects: this constitutes a cooperation channel that must be developed.

Is the CDM really capable of helping DCs to embark on the path of sustainable development, through its influence on energy choices across all sectors of the economy? More precisely, is it sufficiently influential to encourage all sectors of the economy to make energy choices that are compatible with the challenges highlighted here? The answer given by current projects is clearly no: only the large industry and energy production sectors are really affected. Conversely, *there are no projects concerning infrastructure, urban development* (construction, transport) or *the production of efficient equipment*, which are nevertheless essential issues in terms of both energy and climate objectives. Out of all the CDM projects declared, less than 4% contribute to these sectors, for negligible volumes of carbon credits. But does this fact reflect characteristic difficulties of the current learning phase, or does it reveal more fundamental difficulties?

By nature, the CDM can only influence investment decisions if it brings with it significant additional revenue or guarantees. *In the energy sector*, credits sold forward may cover up to 30% of investment for a wind power project and 25% for a typical energy saving project in industry. In a large number of projects underway, carbon credits ensure a 2 to 3% increase in the internal rate of return and an improvement in the risk profile associated with these projects. In these sectors the incentive effect of the carbon market is in full swing, and rewards for emissions avoided are sufficient to consider developing them on a large scale once the other barriers to the development of the mechanism are removed (especially the clarification of methodologies).

The economic and financial characteristics of investment *in infrastructure projects* are very different and do not inspire the same optimism. In China, for example, the value of potential carbon credits corresponding to the difference in energy efficiency between a standard building and an efficient one only correspond to around 3% of the construction cost – a value that is far from enough to motivate private pro-

Fig. 2 **The CDM carbon market**



Source: UNEP Risoe, 2006.

moters, who may make a profit of around 100% on this kind of operation. However, potential rewards are comparable to the extra cost of better insulating buildings: CDM revenue could be recycled by the public authorities in the form of premiums to promoters, for example as part of a labeling program that would make it easier to apply standards that are currently disregarded. A similar observation can be made *for public transport infrastructure*, since the potential contribution of the CDM to the construction of a tramway is around 1% of the total investment cost.

The CDM is clearly not enough to influence infrastructure choices, despite the fact that these investments have not only a considerable impact in terms of CO_2 emissions, but also significant socio-economic benefits. This paradox is due to the fact that the amount of investment in infrastructure related to services provided (housing, transport) is very high in comparison with the energy content of these services. This reveals the limits of the carbon market as a mechanism for encouraging the energy adjustments needed in DCs: in addition to a higher carbon price than the current rate, the heavy involvement of the public authorities is needed if the lever effect is to function in these sectors.

Prospects for climate policies in the South

The assessment that can be made of the decade since the Kyoto agreement is in fact rather ambivalent. It is true that DCs remain somewhat reluctant about a negotiation that could lead them – at least the wealthier among them – to make binding action commitments. From this point of view, the difficulty developed countries are having agreeing on the implementation of the Kyoto Protocol and the plans for the next episode after 2012 do not create a favorable climate for their mobilization. The impact of the CDM, which varies significantly depending on the sector and the country, has also caused disappointment, even if this was largely anticipated.

But these difficulties should not overshadow a far more positive fundamental development: beyond the few emblematic industrial projects that have been criticized, a real attempt is being observed in certain DCs to adopt the CDM and to ensure it works in favor of domestic policies. Several of the projects recently submitted to the executive board fit into this approach: improving lighting efficiency or implementing an energy efficiency standard for individual air-conditioning units in Ghana; reducing electricity consumption for urban lighting in Shijiazhuang (China); and reducing emissions linked to the development of public transport corridors in Mexico (a project submitted by a public company under the responsibility of the Mexican ministry of transport)[7]. In both Mexico and Ghana, the CDM is thus clearly supporting the implementation of local initiative policies. In turn, these activities affect the international debate, and this is where the true development lies: emission quotas and commitments are no longer discussed solely *in abstracto*, but also in more specific terms of energy policies, urban development or rural planning, and consideration is now given to the coordination tools capable of encouraging and supporting these internal dynamics.

New opportunities after the Montreal conference

Within this movement, proposals are being made for ways to move beyond the limited framework of the CDM and develop incentive mechanisms that provide possibilities for crediting more global initiatives: they could, for example, cover the whole of an industrial sector or the implementation of sectoral policies and measures[8]. The common philosophy of these proposals is to conserve the incentive aspect of the CDM by allowing DCs to capitalize on emissions avoided by these domestic activities on the international carbon market, without first obliging them to make quantitative results commitments, and therefore without penalties in case of failure. The eighth decision[9] of the Meeting of the Parties to the Kyoto Protocol, which took place in Montreal, thus extended the CDM to include the notion of "a programme of activities [...] registered as a single clean development mechanism project". This is a key decision in allowing access to the CDM for activities that were hitherto excluded: in particular, if developing countries' public policies will not be eligible, as they stand, under the CDM, the executive board may accept that activities or programs of activities undertaken for the implementation of these policies comply with the mechanism and may therefore be credited.

By opening the way for broader and more diversified sectoral initiatives than the CDM, these different incentive mechanisms could have a significant impact in terms of emissions, while contributing favorably and sustainably to development in host countries. But like the CDM, they do not reduce global GHG emissions and work simply by moving emissions from developed countries to developing countries, accompanied by a financial transfer in the opposite direction. Their existence and their appeal are therefore directly linked to the constraints accepted by Annex I countries (the part of the Climate Convention that sets out the list of countries committed to binding targets). Today the demand for CDM carbon credits is thus largely dependent on the connection between this mechanism and the internal European market for CO_2 emission permits. The total volume of credits generated by project mechanisms cannot exceed the emission reductions to be achieved in Annex I countries. It is in fact vital that they remain well below this level, as the contrary would mean that developed countries have not truly implemented domestic climate policies.

The estimations mentioned earlier concerning projected demand for CDM credits in Annex I countries represent between 5 and 50% of the current commitments of these countries. With global GHG emissions reaching 33 000 $MtCO_2$, the annual flow of CDM credits during the 2008-2012 period will therefore be around 0.3% of global emissions and 0.6% of developing countries' emissions, which falls far short of the emission reduction targets mentioned earlier: growth in developing countries' emissions must be limited to 50% by 2050, which, in relation to an estimated trend growth of 2.5% per year, means that credit purchases in the future must cover over 1 000 $MtCO_2$ of annual reductions. It is highly unlikely that developed countries will simultaneously achieve significant reductions in their domestic emissions and make CO_2 credit purchases on this scale – corresponding to a twofold increase in their domestic efforts – when their initial aim was to reduce commitment costs. On the contrary, this situation could cause significant distortions of competition liable to ensure rejection by manufacturers in Annex I countries if, for example their credit purchases contribute to financing investment in rival industries situated in emerging countries; industries that would not only be assisted in modernizing, but would remain free from any carbon restrictions.

What is the future for climate regimes?

The challenge posed by the climate issue is not reaching an agreement on symbolic indicators or rights, but rather defining a framework capable of directing and stimulating long-term dynamics (investment, technological innovation, infrastructure development, etc.), beginning with short-term projects that will nevertheless help outline emissions trajectories for DCs over several decades. An international cooperation framework of this kind should thus guarantee the transition from the current socio-economic model to 'low-carbon' societies. The very existence of such a framework is conditioned by its ability to manage the inherent constraints of this transition, especially in terms of its redistributive effects and its potential impact on the most vulnerable countries or populations.

The modalities for involving DCs in the fight against climate change must therefore be more diverse than they are today. Given the dynamics of international negotiations, it is particularly unlikely that developed countries will commit to ambitious action targets if emerging countries do not accept to progressively submit their energy and industrial sectors to similar discipline. This would consequently limit the scope of incentive mechanisms to the sectors or countries in which they are the most valid. The implementation of energy efficiency policies in emerging countries, which does not pose the same problems as investment in industrial sectors open to international competition, could become a key focal area. This movement would also benefit LDCs, provided it is associated with more active support from cooperation policies for the organization of projects.

However, market mechanisms will not be sufficient to redirect heavy investment in major infrastructure in the long term. But as illustrated by the difficulty European countries have in reorienting their transport policies and adjusting the energy efficiency of their buildings, neglecting these sectors today may rapidly lead DCs, and especially those with high growth, towards highly irreversible and unsustainable energy models. China, and also certain large Latin American countries, are gradually becoming aware that the development of more energy efficient infrastructure can also contribute to more balanced economic and social development in the short term. These sectors nevertheless remain strikingly absent from major international initiatives, which currently focus on supply technologies (clean coal, sequestration and hydrogen). It is therefore vital to restore balance to international community efforts and to grant these key areas a similar level of attention.

[a] A resolution adopted by the American Senate set this as a precondition for the United States' entry into a binding mechanism.

[b] This generic term describes the units of measurement for GHG quotas, reduction or sequestration controlled by the Kyoto Protocol.

[c] On this point, DCs benefit from a rule concerning the non-diversion of ODA, to ensure that the CDM is not used as a means of financing the achievement of binding targets to which Northern countries have committed.

[d] This is for declared projects. Projects registered in April 2006 represented 53 $MtCO_2$ per year, and projects representing 27 $MtCO_2$ more were being registered.

[e] Recent research forecasts an annual demand for carbon credits, for all mechanisms (quotas, JI or CDM), of around 870 to 1 000 $MtCO_2$ – or half of initial estimations, which included the United States.

[f] The surplus quotas linked to over-allotment of emissions in the targets set for Russia and central and eastern European countries in Kyoto, which did not include the impact of their economic collapse.

[g] Related to the oil industry, these projects in Nigeria are not representative of the region's needs.

[h] In particular, China has created a specific tax on the carbon credits created by some CDM projects in the country.

[i] The predominance of these projects is explained by the fact that the global warming potential (GWP) of these gases is very high (from 300 to 25 000 times higher than CO_2), which increases the associated carbon credits and facilitates their global implementation through technical 'end-of-pipe' solutions.

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The Kyoto Protocol, which is an imperfect diplomatic compromise, has attracted criticism from all quarters. It nevertheless represents the political legitimacy of an international climate change mitigation regime. Since it is impossible to reach consensus on the principles of equity in such a regime, the diversity of the various situations and the urgent need for effective action, the architecture of the Protocol remains the only possible international coordination framework for extending emission reduction targets to developing countries. This is provided the Protocol is adapted with one priority in mind: the tools of the climate regime must become levers for development policies.

An international coordination regime come what may

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The system of emission quotas accompanied by negotiable emission permits (cap and trade), on which the Kyoto Protocol is based, is the result of a series of diplomatic compromises. This type of coordination was based on the central idea that only a single price could minimize costs in order to meet reduction targets and avoid problems of distortions of international competition. Cap and trade was seen as a way of reconciling economic efficiency with the goals pursued in environmental policies, and universal participation with national sovereignty, without any apparent inconsistency with other environment treaties or national development objectives. The limitations of this system, in particular the lack of credible proposals for developing countries (DCs), would indicate that a new balance should be struck between long-term climate policies and development trajectories in order to propose an architecture for an international regime capable of incorporating DCs.

The limitations of cap and trade

The international regime set up for the climate change dossier, with its specific system for greenhouse gas (GHG) emission quotas and the associated market, is in fact unconnected with the other aspects of international governance (energy, international trade, innovation, etc.). Nevertheless, from the outset specific objections have been raised to the central principle that emerged from the Kyoto Protocol negotiations, and the follow-up to this process has not provided any response:

- In a resolution adopted by the Senate in 1997, the United States declared that it would reject any protocol that did not provide for significant commitments on the part of DCs. This entailed both refusing a one-sided restriction on the economy and insisting on a principle of "no votation without participation[1]", whereby only those countries wishing to take part in the system would be entitled to discuss the details of that system.
- On the penultimate day of the Kyoto Conference, the developing countries' negotiating group (a coalition of the Group of 77 and China) declared that, *"so long as the question of emission permits and their allocation was not managed in an equitable manner, no quota trading would be possible"*.

During the discussions on the emergence of a carbon market, economists systematically omitted to point out that the application of an economic coordination tool devised in a theoretical and perfect world could have unintended consequences in a real and imperfect world: in DCs, markets are incomplete and fragmented, with little governance and scant protection of property rights, and are also structured by a dual economy that is constantly changing. Moreover, in countries experiencing various transitions, and where highly varied generations of technology are in use, the effect of the carbon market on investment options can only be mild, which could have unintended consequences.

A carbon market not geared to DCs

In many DCs, the emergence of a carbon price is liable to encourage a move towards energy sources that are free, but which are inefficient and emit large quantities of GHGs, and may also act as a brake on the development of the traditional sector, for example by restricting access to electricity in rural areas. Conversely, factors that could lead to development trajectories that generate fewer GHG emissions are not affected by the carbon price: intervention on interest rates and salaries could in fact have a greater impact on the development of the formal sector in rural areas than the carbon price, in terms of both local development and GHG emission reduction.

Furthermore, *there is too much uncertainty about what DCs would gain from the carbon market.* The transfer of capital it should generate from the North to the South, which is one of the principal arguments in persuading DCs to participate in the system, is still not sufficiently convincing. The results of global models[2] in fact show that the majority of these transfers will not go to DCs, but rather to Russia and the Ukraine because they were allocated excessively high quotas in view of the collapse of the Soviet system. And it is unlikely that the industrialized countries bound by Kyoto Protocol targets will agree to new kinds of transfers by adopting rules that will lead to generous quotas for DCs.

One less evident but fundamental reason why DCS may reject carbon trading is that there is some doubt as to whether these transfers will have a positive impact on development. In most general equilibrium models, any influx of money into a country directly increases per capita income. Things may be different in the real economic world. For example, *because of differences in purchasing power and exchange rates,* the impact of *a single carbon price expressed in dollars* on the price of energy would entail a greater increase in the proportion of household budgets spent on energy in DCs than in Europe or the USA. The final impact would be positive only if this effect on income were offset by profits arising from carbon trading – and that would depend on how that capital was recycled within the national economy.

Finally, the requirements of environmental integrity in the application of the Clean Development Mechanism (CDM) defined in the Protocol *are intended to ensure that only real emission reductions are eligible.* This excludes from the mechanism projects where a certain level of precision in measurements cannot be guaranteed: projects not carried out in the baseline scenario, but which would have a significant impact in terms of both development and avoiding GHG emissions, are not therefore eligible under the CDM (cf. Colombier et al.).

This series of restrictions has contributed to the growing skepticism of DCs, all the more since industrialized countries have carefully avoided going any further than merely talking about accompanying measures and have not acted upon the Brazilian proposal for *an observance fund* to be financed by the penalties paid by those countries that fail to meet their targets and by extending the share of proceeds[a] tax to all flexibility mechanisms.

Agreement impossible on the principles of equity

The guiding principles of equity surrounding the climate change dossier will inevitably need to be reworded. However, this issue has not been resolved by current agreements, which endorse the lack of commitments for DCs for the first Kyoto period and fail to address issues concerning allocation for the subsequent periods.

The most controversial proposal suggests a uniform distribution of emissions on a per capita basis[3]. Using the rhetorical proximity between the concepts of equity and equality, this rule acts as a counterbalance to the environmental neo-colonialism of the current rule of acquired rights (known as 'grandfathering'), which consists in defining reduction targets as a percentage of emissions for a given baseline year. This proposal has become an inescapable political pillar in negotiations. The principle of acquired rights, already broadly practiced in international agreements, is based on different ethical principles: any new environmental negotiations constitute a renegotiation of the social contract, and it is fair to take into account the rules that applied in the old contract when drawing up the new one.

Do current emission levels give any rights to the future use of the atmosphere (as a dump for industrialized countries' emissions) since this is a new problem that was not previously known? Different proposals for differentiating the rates of reduction applicable per country have been drawn up in response to this criticism and in order to take into account real reduction capacities and growth requirements when allocating initial quotas. One such model – in order to avoid imposing an additional short-term restriction on development – sets the rate of reduction for each country in proportion to the difference between its per capita income and a level under which countries are not bound by reduction targets[4].

At a more general level, allocation rules need to be devised that bridge the gap between these two opposing principles, based from the outset on the principle of acquired rights and containing different representations of the principle of contraction and convergence, according to which *global GHG emissions must be reduced globally at the same time as moving towards a uniform per capita level* (decreasing to zero in the long term)[5].

One alternative, which cannot be categorized between the two extremes, is the Brazilian proposal to *base the distribution of efforts on an assessment of the differentiated historical responsibilities of the various countries* in anthropogenic climate forcing[6]. By extending the 'polluter pays' principle to the global level, this proposal has raised considerable scientific interest within the Intergovernmental Panel on Climate Change (IPCC), but it comes up against operational stumbling blocks that are difficult to overcome, in particular uncertainty with regard to attributing historical responsibility for global warming.

The reasoning behind the competition between these rules is the level of acceptability to each of the participants of the consequences they would entail. There are, however, many criteria for assessment (total cost of reduction, carbon price, financial transfers generated by the permit market, impact on well-being, etc.)[7] and, in view of the effects of general equilibrium, there is no direct connection between gains or losses in well-being and the carbon price or the quantity of carbon credits traded. There is still considerable doubt that agreement will be reached on a rule, all the more so since, although certain countries are showing a marked preference for the second commitment period (per capita allocation for DCs or according to acquired rights for the United States), preferences become unclear when the moment comes to define the global rules for an agreement. Certain countries even favor different rules depending on the deadline in question: thus, China and Europe, for different reasons, both reject the rules based on the principle of convergence by the year 2030, but would accept them for the immediate post-2012 period.

Radical changes could also be made to allocation rules for each new period, but this would harm the dynamic efficiency of the system. Moreover, in view of the time elapsing between the moment targets are set and the end of the period they cover (10 years, 15 years for Kyoto), the baseline scenario is very uncertain.

It will no doubt be impossible to find an explicit formula that represents the equity question in a manner acceptable to all. Priority should therefore be given to devising policies that combine a positive impact on both emission reductions and development: the very concept of sharing the burden of reduction efforts, which lies at the heart of the debate on the allocation of emission quotas, would thus become irrelevant.

Development trajectories and climate policies

It is generally thought that the environment imposes new constraints on baseline scenarios for development. Perhaps win-win strategies can be used to devise a way to combine climate change policies with development policies in order to build a coordination regime.

Economists generally claim that DCs have high GDP growth rates because it is politically incorrect to speak of crisis scenarios, but also because of the limitations of the models used: economic growth is a factor of partial equilibrium models and a result of general equilibrium models, which build up 'golden age' growth. However, baseline scenarios are highly uncertain and less than ideal: climate policies are a step towards bringing them up to optimum level.

Baseline scenarios for development

The founding concept of sustainable development, defined in Stockholm in 1972, is that environmental disturbances exacerbate the unintended consequences of different development models (distortion in technological options, structural unemployment, basic needs that are not met and the rural exodus). This concept can be updated today.

1. *It is difficult to bridge the gap between domestic saving capacities and capital required to develop infrastructure.* Total investments in the energy sector between 2001 and 2030 should reach 2 200, 2 100 and 1 300 billion dollars in China, the rest of Asia and Latin America respectively[8]. It is estimated that between 2005 and 2020, 6.7% of GDP in the Asia-Pacific region should be invested in transport infrastructure, water supply and sanitation, and 5.5% in the energy sector. Whereas 40% to 60% of saving in a country is normally used for construction, investments are already under considerable strain in Africa, where the saving ratio is only 8%. In China, current saving levels (35%) are expected to fall significantly in the decades to come with the inversion of the age pyramid; with infrastructure needs increasing more rapidly than GDP, China may experience a debt spiral similar to the one in Brazil in the 1980s[b]. Assuming that investment in infrastructure that makes low-carbon development models possible, for example in the development of towns, is not made today, then the strain on capital described above would make it impossible to move in a different direction.

2. *The liberalization of world trade demonstrates a highly uncertain link with development*: it has failed to encourage private sector investment in infrastructure or to make local food production, which suffers serious competition from cheap imports, a viable option, whereas agricultural sectors intended for export are very profitable; liberalization has destructured sectors that had remained outside international markets in a system largely considered to be dominated by Western interests and multinationals. At the same time, the South is increasingly concerned that there may be a protectionist backlash in the North. Finding the answer to these two contradictory concerns is all the more difficult given the fact that DCs are at different stages in the liberalization process.

3. *The revival of tension with regard to energy security*, which is as much due to the controversial peak oil date as to the concentration of conventional oil reserves in politically sensitive areas, is liable to disrupt economic growth in oil-importing countries. The key issue here is knowing to what extent policies that address these concerns are able to help mitigate climate change and, similarly, to what extent the circulation of low-carbon technologies can help guarantee energy security and, moreover, encourage sustainable development by reorienting the local use of resources, technological options and consumer patterns, whilst at the same time protecting the earth and carbon sinks.

The lever effect of climate policies on development

Because of the many socio-economic restrictions hindering stakeholders in DCs, the most frequent situation is one of 'business as usual', understood here to mean a lack of investment and well thoughout collective projects. Precarious, unsatisfactory solutions ensue, with negative external consequences: obsolete and often defective production equipment, dangerous working conditions, unplanned self-help construction, congestion and ever more rundown vehicles, uncertain, insanitary and costly energy sources and water supply, etc. The causes may be listed[9]: lack of technological know-how, insufficient return on investment, informational asymmetries leading to moral hazards[c], financial restrictions limiting access to capital, market distortions, non-monetary hidden costs and cultural acceptability, etc. These are classic problems within a development economy: the needs and solutions are known, but there are various obstacles to their achievement. Finally, when it becomes possible to remove the causes of these obstacles, the most beneficial (or least harmful) alternative for the global environment will not necessarily be chosen.

The quest to find a lever effect for development within climate policies aims to create incentives for removing obstacles and making it possible to achieve the best alternative in terms of emissions. But the imposition of a carbon price, by increasing the profitability of climate-friendly technologies, reduces the relative profitability of GHG-emitting technologies. In this case the government would receive aid to implement accompanying policies for these zero-emission technologies.

India is a good example of mechanisms in use. Climate policies may give rise to the implementation of development actions that would not otherwise have existed. This is directly relevant to the debate on the potential for 'no regrets' actions that yield both financial gain and environmental benefits (typically energy efficiency improvement measures or projects); the Second IPCC Report (1995) made great mention of the fact that there were many such potential opportunities in DCs, but commented in a broader sense on the possibilities for changing the baseline scenario itself.

Box 1 Reform of the electricity sector in India

At the beginning of the 1990s, India set about a large-scale plan of reforms for liberalization of the electricity sector. The result of those reforms was to make the sector more dependent on domestic coal at the expense of hydroelectric power. The carbon content of electricity has been rising ever since.

In 2002, the Planning Commission of India drew up an alternative scenario, the 'best case scenario' (BCS), presenting a possible alternative for the sector making it possible to reduce emissions in 2020 by 81 million tons of carbon as compared with the trend scenario[10]. This scenario is based on a series of initiatives being carried out in this sector: the modernization of existing power plants to make them more efficient; savings on the transportation and distribution of electricity; the adoption ahead of schedule of advanced technologies; regional cooperation on energy matters; and, finally, an increase in market share for hydro-electricity and renewable energy sources (in particular by the introduction of subsidies for renewable energies and the gradual phasing out of those for domestic coal).

Such action would make it possible to reduce local pollution and GHG emissions, rationalize government expenditure and improve the returns of economic operators within the sector. However, in the present context this action has not been carried out, raising the question of whether or not the implementation of a climate regime would encourage such action, leading the Indian electricity sector onto a more sustainable trajectory.

The BCS policies would clearly benefit from the application of a carbon price[11]. This would in turn increase the profitability of low- or zero-emission technologies (gas or renewables) whilst at the same time reducing that of coal-fired power plants. This development would attract foreign investment in clean technology principally through project mechanisms. Such investment, replacing domestic investment in the sector, would free up Indian capital for other projects or other sectors.

Towards a reinterpreted, improved and enhanced Kyoto Protocol

The deployment of the future climate regime must be capable of linking complex issues concerning principles with very diverse situations. Many criticisms leveled at the Kyoto Protocol highlight the impossibility of defining an overall architecture irrespective of the other dimensions of international governance and stimulated proposals for 'fragmented regimes' with coalitions moving progressively together.

This approach, dubbed the "Madisonian approach[12]", would give stakeholders greater flexibility in adjusting to the harshness and surprises of the real world (regional agreements on technologies, voluntary agreements on car manufacturers, etc.). This is, for example, the thrust of the recent Asia-Pacific agreement on technologies[c]. Political realism would suggest, moreover, that it is unlikely that countries such as India and China will enter into legally binding quantified emission reduction commitments in the short term, if this is the only 'offer' made to them. Unfortunately, this flexible approach is unlikely to result in significant action or, above all, in economic signals that are sufficiently stable and credible to allow for immediate action in the major infrastructure sectors.

Finally, despite the criticisms that may be directed at the Protocol, its architecture is the only kind possible for two reasons: *political*: it is diplomatically impossible to sweep away a treaty ratified by over 100 countries that has achieved a high level of legitimacy; *economic*: no alternative provides the same potential for untying the inextricable Gordian environment-development knot.

An international carbon tax would pose the same problems of equity as the cap and trade system, without the possibility of compensation by means of generous quota allocation[13]. In the absence of financial transfers and given the present state of tax systems, highly optimistic theories must be developed in order to envisage mechanisms that would generate double dividends arising from national tax reforms making it possible to provide full compensation (and it is unlikely that international aid will be capable of generating transfers on the same scale as those arising from a system of tradable quotas).

More rapid progress in research and development (R&D), as the American government wishes, is essential for the success of climate policies. However, few technologies can be deployed in the absence of economic signals, particularly price signals. A purely technological approach, suited to the major research programs such as space exploration or fusion, does not work on the scale of the hundreds of final services that must be deployed in each specific context.

The only solution is therefore reinterpreting the architecture of the Protocol in order to make it easier to draw upon environment-development synergies. This implies redefining the cap and trade system within a new negotiation model.

Redefining the climate regime paradigm

DCs are undergoing numerous structural transitions. These give rise to the emergence of regional trading blocs and to greater participation in international trade, which alters the dynamics of World Trade Organization (WTO) rounds.

The most advanced DCs are aware that their increasing wealth justifies accepting emission limits. They will do so if they are aware of the synergies existing between energy security, the environment and infrastructure as a factor of development, but they will request that climate change objectives be aligned with development objectives[14]. This suggestion is made in numerous national communications to the UNFCCC and governments have issued further declarations to that effect: the Millennium Summit Declaration (2000), the Johannesburg Declaration at the World Summit on Sustainable Development (2002), and the Delhi Declaration on sustainable development and climate change (2003).

The form such offers may take is a sensitive issue, since the international context is far more complex than it was in 1992 or 1997. The mistrust of the larger emerging countries and the threat they pose to employment make it difficult to imagine significant transfers to DCs to encourage them to participate in climate action. This is why developed countries must be honest about why they want climate policies: is it only for environmental reasons, or to ward off the political instability that climate change could entail in regions with little capacity for adaptation, or for geopolitical energy reasons, or perhaps because they are one of the factors of international security?

The recent G8 declarations on climate change and the reduction of poverty call for an extension of the negotiation paradigm: *climate policies may be seen as a factor for turning economic globalization into a mutually beneficial process* instead of a tough competition between nations. Over and above arguments about security (energy, climate refugees and political instability), the North will make serious offers only if it sees in the participation of DCs some potential for stimulating its economic growth. In this sense, the demand for infrastructure in the South may be regarded by the North as a veritable Marshall Plan. The principle of universal solidarity does not therefore necessarily denote altruism or 'benevolence', but also well-informed perceptions of selfish interests. A negotiation mandate that states these positions has more chance of reaching a compromise and an ambitious climate objective than the mandate applied up to now[15].

In this new negotiation paradigm, based on acknowledgement of the links between each of the different dimensions, the reference values for emissions (baselines) are themselves an intrinsic part of negotiations since they represent decisions and compromises in other fields of governance: the WTO, international financial reforms, gas and oil markets, labor rules, environmental standards, etc. This has decisive implications for the specific role of these international negotiations:

- *The climate regime cannot claim to dictate critical decisions concerning the decarbonization of the economy*, and may even be limited to the selection of win-win policies that would help to mitigate climate change. This implies giving priority to operational approaches in line with the long-term economic signals reflecting the social value of reducing GHG emissions.
- It must *pave the way for varied initiatives rather than dictate uniform solutions*, in order to take account of the heterogeneous nature of the real world and to ensure that economic signals are predictable. It must have room for all kinds of regional or sectoral cooperation *and avoid any risk of fragmentation* – in the manner of a 'favela' – in a wide range of agreements between groups of countries (like the Asia-Pacific agreement) with no international coordination or regulation.
- It must *support rather than hinder domestic policies*. In this respect it is important to define the concept of legally binding commitment since, on the one hand, no economic signal will emerge without a certain form of commitment and, on the other, many countries will not accept a system that restricts their sovereignty. The key to a secure system lies in both the benefits all governments will reap by respecting their commitments and in the cost of economic and political sanctions should they fail to so.

Minimalist architecture in a changing world

Such minimalist architecture – sketched out in the four points below – could be built upon the basis of the Kyoto Protocol with just a few amendments. In view of the criticism the cap and trade system has attracted, the first objective would be to seek synergy between the environment and development.

The role of the carbon price

Taken alone, the carbon price will not be sufficient to achieve decarbonization. Whatever the importance attached to it, this long-term economic signal will have no influence on a number of parameters such as capital costs, insurance premiums, certification of alternative technologies, the structure of tax systems, etc. *The problem must be approached from a different angle*: the long-term prices fixed by the carbon market must constitute a reference for evaluating the climatic benefits of all types of initiatives on the ground. This first implies not using environmental integrity as grounds for systematically rejecting the idea that a ton of carbon avoided has to be duly measured to be credited; this is clearly absurd when the *potential benefits are far greater than the ambiguity surrounding measurement.*

In other words, the cap and trade system is a key element of this architecture, but not the only one. In practice, market forces operating in the allocation of quotas to private operators will ensure part of the decarbonization process. Although non-measurable reductions (for example as the result of speed limits) could be traded only between States, they would nevertheless contribute to market dynamics by reducing carbon imports or increasing exports for any country applying this measure. In this scenario governments remain the key operators in the system since they control not only reduction targets, but also the number of sectors to which emission quotas are allocated and the degree to which they can operate on the international market. Governments thus retain their full autonomy.

Diversified commitments

The first condition for persuading DCs to accept the cap and trade approach is to abandon any idea that emission reductions may hinder development. This is possible if commitment modalities are diversified according to the country's situation. Thus, binding commitments for Annex B countries and for countries achieving a certain per capita income level could be coupled with more open mechanisms for other countries:

- non-binding commitments[16]: countries respecting this commitment would have access to the international carbon market, but would not be penalized for failure to respect the commitment;
- sectoral objectives: a country would be allowed to participate in the global system only as regards certain sectors of its economy where the impact of such participation on its development would clearly be positive;
- certain kinds of clean development mechanisms extended to programs supporting action in countries and sectors not yet mature enough to adopt severe restrictions on emissions;

There is a second argument in favor of shelving a single system for negotiable emission permits covering all countries, sectors and GHGs. In the event of market distortion, this system harbors the risk that all investments made to reduce emissions will be devalued; such distortion may arise, for example, from a continuing surplus of quotas allocated in relation to needs (hot air) or from ambiguity surrounding the measurement of initiatives for non-CO_2 emissions or carbon sequestration projects. Sectoral objectives provide an opportunity for entering the system in a more progressive and controlled manner.

The introduction of non-binding commitments has one major drawback: it is not possible with this system to determine a final level of emissions. But the alternative is that DCs may not even consider the idea of reducing their emissions. Instead, if only binding commitments were considered, the risk would be that these countries could put all their efforts into negotiating lenient objectives, which would be granted under Annex B in order to bring them into the system at the cost of a considerable devaluation of carbon. There are three ways of circumventing this problem:

- The absence of penalties should encourage a more frank dialogue, where Annex B countries and candidate countries have a joint interest in preventing carbon devaluation.
- Emission targets based on performance criteria (rather than on absolute values) could rely on observable data in order to limit the risk of hot air whilst being less sensitive to fluctuations in economic growth. Linking objectives to performance also helps to avoid the idea that development is being held back.
- The introduction of a carbon floor price[d] may constitute another means of preventing a fall in carbon prices.

Finally, in a system incorporating different types of commitments, governments are not obliged to increase all domestic prices. They select those sectors for which there are considerable anticipated gains from the carbon market as compared with the effects of a rise in energy prices.

Good faith commitments and incentives

The proposal made in 1997 for a carbon price ceiling[17] was intended to reduce uncertainty about how much it would cost Annex B countries to fulfill their commitments and also to introduce a maximum price into the system, making it possible to negotiate more ambitious objectives. This solution constitutes a compromise between the optimists and the pessimists as regards reduction costs: if reduction costs are above the price ceiling then extra permits are sold at that price, which introduces a guarantee and limits countries' total bills; if costs are low the ceiling price does not apply.

The main criticism made against this mechanism is that there are no sanctions for non-compliance. This reflects an erroneous understanding of the concept of a 'legally binding' commitment since, apart from military intervention, the only effective sanction would be political and economic reprisals against those failing to comply. With a price ceiling, unfulfilled commitments are 'paid for in advance', because in this case extra permits are placed on the market at the ceiling price. In order to improve environmental efficiency, the funds collected, in line with the Brazilian proposal[e], could be paid into an international fund for financing reduction projects, giving priority to LDCs, which will no doubt remain outside carbon trading. Annex B countries are also encouraged to adopt more ambitious domestic 'non-price' policies by controlling their external balance of payments.

From a purely economic point of view, a hybrid system incorporating both a floor price and a ceiling price would limit uncertainty about costs and would provide valuable information on the price/quantity relationship for emission reductions that would provide guidelines for long-term decision-making.

A mechanism for energy-intensive industries

The creation of an international regime will inevitably face opposition from carbon-intensive industries that are exposed to international competition, and would meet with imbalanced restrictions from countries that were bound by commitments and those that were not. This risk is often overestimated on the consumer market: the impact of carbon prices on production costs has been less than the exchange rate fluctuations over the past 30 years[18]. The risk is greater for the stock value. Distributing a small portion of quotas free of charge is a means of disregarding this, but this would not be the case if a government were to distribute a generous amount of quotas free of charge and to auction off the remainder.

This is a real problem: no government is in a position to resist pressure to safeguard jobs. However, since it falls to the government to apply different targets and domestic carbon prices to households and industry, carbon trading takes place essentially between governments. Carbon prices will differ from one country to another and from one sector to another, and it is only for energy-intensive industries facing international competition that carbon prices need to be leveled out at the international level. This does not solve the problem of rules governing quota allocation or the many potential disagreements with the WTO, which is why a specific international agreement on these industries is needed.

Platforms based on long-term objectives

The process of drawing up a new framework could come up against urgent financial constraints and the risk of social explosion in DCs if the benefits of participation are not immediately tangible. Given the time it takes for the positive impact of decarbonization on development or of damage avoided to become apparent, other incentives should be found in the short term. This is all the more pressing since, despite recent debt cancellation in the poorest countries, official development assistance (ODA) figures fell significantly before rising again since 2002. Furthermore, although the removal of barriers to development may contribute to decarbonization, other components of development policies are likely to generate carbon-intensive technological trajectories. Starting today, it is essential to ensure carbon-intensive technologies do not appear the better option.

With this in mind, it is important to re-position climate policy instruments in the context of international assistance and transition financing. GHG emission trajectories are as much the result of transport policy choices (pricing, control, etc.) as of infrastructure development, urban planning (location of commercial centers or new residential areas) or social housing policies, etc. Although a carbon price alone, even a high one, cannot make its mark on all levels of decision-making, these fields still often depend on ODA financing in DCs. In other words, climate policies can no longer be divorced from development policies and development financing methods.

The sensitive issue of establishing a link between climate policies and multilateral development funding has focused on the fear of a crowding out effect. This debate could have been closed thanks to additional sources of funding: compliance funds, share of proceeds tax extended to the three flexibility mechanisms, bunker tax, aviation tax, etc.

On the one hand emerging countries such as China, India or Brazil, the chief recipients of foreign direct investment (FDI), require aid that is no longer strictly financial support. These highly volatile funds do not have the characteristics required to meet decarbonization objectives and the demand for energy. ODA must play a role in institutional and technical facilitation (support for structural reforms, partnerships between the private sector, banks and public bodies, etc.) On the other hand, the construction of infrastructure in LDCs is heavily dependent on ODA funding. In these countries the potential (in terms of volume) for reducing emissions is low; ODA funding should focus on financing adaptation and capacity building. Climate policies and the management of associated emission reductions offer a further opportunity for monitoring the effectiveness of ODA. This implies institutional innovations aimed at controlling both investors and host countries and ensuring that the money associated with climate policies is being put to good use.

Private investment is closely bound up with the visibility of long-term trends. Investment that is climate-friendly in the long term, such as infrastructure investment, is subject to different types of risk (exchange rate, levels of demand, etc.), which explains why it is so volatile. Within the context of climate policies, development funding institutions should be able to provide instruments for reducing risk. Thus for the PLANTAR project in Brazil, a commercial bank that appears in Annex B has issued a loan through the Prototype Carbon Fund with repayments scheduled to coincide with expected emission reduction credit payments. Insurance contracts could also be linked to climate-friendly initiatives in order to release funds upstream of the project: this is the case for the Emission Reduction Purchase Agreement (ERPA), which mitigates exchange rate risks and includes credit agencies that release a part of the capital upstream.

The link between environment and development: an urgent matter

Negotiations concerning the post-2012 period must not get bogged down in endless rhetorical differences between a 'grand architecture' and an array of alternative proposals that would in fact lead to a 'favela'-type approach.

Urgent and serious thought must be given to the link between the environment and development, making it possible to find a way out of this dead end. This can only be achieved if a move is made away from viewing the climate issue in isolation within the international agenda – which has been the case since 1992 – to focusing on environmental integrity, in order to define a menu of varied objectives capable of encouraging the active participation of DCs. The viability of this coordination regime will depend upon an institutional design enabling carbon revenue to remove the barriers to development.

This is not to say that the Kyoto Protocol – which has acquired considerable international legitimacy – should be abandoned, but its centrist climate policies must be reinterpreted in order to expand the range of mechanisms: non-binding commitments, ceiling prices, floor prices, voluntary agreements in key sectors of industry, and a redefinition of the CDM so that it takes account of infrastructure investment programs. But the most important point is without doubt the recognition of the nature of its relationships with the whole range of issues: energy security, local environment, debt traps, social dualism, and the reform of international financing and ODA.

[a] The 'share of proceeds' denotes the tax applicable to funds generated by the CDM to sustain an adaptation fund intended for those countries that are most vulnerable to climate change.

[b] Brazil's energy sector then accounted for approximately one third of the national debt.

[c] A loophole in a regulatory or contractual system that opens up vast possibilities for abuse or produces unintended consequences.

[c] Partnership agreement signed in June 2005 between the United States, Australia, Japan, China, India and Korea.

[d] Accompanied by a subsidy for reduction project developers when the cost of reduction is below this floor price.

[e] This proposal was that penalties collected from countries for non-compliance should be paid into a fund to finance the actions of DCs.

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As growing contributors to CO_2 emissions and the first victims of climate change, developing countries must assert their position in international climate negotiations. But their involvement is only meaningful if their development objectives are fully taken into account. Consolidated sustainable development policies would be a step towards limiting their emissions: this approach, which paves the way for voluntary commitments, is beginning to be formalized and discussed in the context of the Climate Convention.

The perspective of developing countries

José Goldemberg

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The true nature of the Climate Convention

Climate negotiations began in earnest in the preparatory process that led to the adoption of the Climate Convention in Rio de Janeiro in 1992, amidst considerable euphoria in the environmental movement.

The Climate Convention resulted from the scientific work of the IPCC (Intergovernmental Panel on Climate Change), which in its Third Assessment Report[1] pointed out that "emissions of greenhouse gases (GHG) and aerosols due to human activities continue to alter the atmosphere in ways that are expected to affect the climate". It went further than the two previous Reports, stating that "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities". Consequences of such warming include an increase in the average sea level and significant changes in rainfall.

Greenhouse gases originate mainly from the burning of fossil fuels on which most technological devices used today depend: more than 80% of all energy used in the world is generated using coal, oil or gas. Another significant source of greenhouse gases is deforestation and other changes in land use that release carbon into the atmosphere. The most obvious methods for reducing GHG emissions are therefore reducing deforestation and the consumption of fossil fuels through an increase in the efficiency of energy use or a switch to non-fossil fuels.

The Climate Convention of 1992 recognized that industrialized and developing countries had to be treated differently because the former benefited greatly from the use of fossil fuels in their development process (over the last two centuries) and are today the main contributors to GHG emissions, while the latter are in the initial stages of development and a relatively minor contributor to emissions. The language adopted in the Convention was that both groups of countries had "common but differentiated responsibilities" in facing climate change.

In practical terms the industrialized countries committed themselves to "returning individually or jointly to their 1990 levels". The developing countries were only required to prepare inventories of their emissions and eventually propose reduction policies. The rhetorical use of "common but differentiated responsibilities" was seen by many as an excuse to do nothing.

The Kyoto Protocol

This was, of course, insufficient and since GHG emissions continued to increase, great pressure developed to give 'teeth' to the Climate Convention by adopting binding targets for reductions and a timetable to achieve them. The adoption of the Kyoto Protocol in 1997 succeeded in doing that, thanks to pressure from environmental groups, European countries and the lukewarm support of the United States, represented in Kyoto by vice-president Albert Gore.

According to the Kyoto Protocol, Parties included in Annex I (in other words industrialized countries) shall "individually, or jointly, ensure that their overall aggregate anthropogenic carbon dioxide equivalent emissions of GHG be reduced by at least 5% bellow 1990 levels in the commitment period 2008 to 2012". The developing countries – not significant GHG emitters at that time – were exempted from any limits on their emissions.

It is worth mentioning that the Protocol has no provisions for sanctions against non-compliance, but this is not actually as bad as it might sound because this was partially corrected in Marrakech with the introduction of non-financial sanctions. They apply, of course, only to countries that ratified the Protocol and not to 'free riders'. It is usually accepted that international agreements that do not contemplate strong sanctions are in reality non-binding and depend on the unilateral willingness of participants to comply with them. Even for countries that ratified the Kyoto Protocol and do not fulfill its commitments, there it is very little that can be done about it.

In fact it soon became clear after the Kyoto Protocol was signed that there was strong reluctance in the United States to accept the emission reductions envisaged in the Kyoto Protocol. President Clinton did not submit the Protocol for ratification and the Byrd-Hagel Resolution approved by the US Senate in 1999 stated clearly that it would not ratify it unless the developing countries were also subjected to limits in their emissions. It was also argued that the reductions imposed by the Kyoto Protocol would ruin the US economy.

The Kyoto Protocol allowed 'Emissions Trading' and 'Joint Implementation' among the industrialized countries – in which the developing countries are not involved – and created the Clean Development Mechanism (CDM), with the aim of assisting developing countries in achieving sustainable development and helping industrialized countries to reduce their GHG emissions.

The Clean Development Mechanism was not accepted without controversy; for some environmental organizations it was seem as a measure to provide an easy way for industrialized countries to fulfill obligations to reduce emissions in their own countries, giving them freedom to continue emitting GHGs and offsetting such emissions by activities in developing countries. For others it was seen as a means of transferring resources to developing countries for the implementation of environmentally sound projects, thereby promoting sustainable development. As a whole, the CDM does not reduce net carbon emissions into the atmosphere and can be considered a 'carbon-neutral' system. However, the argument that projects implemented in developing countries under the CDM are in reality a 'zero–sum game' is flawed: without the CDM resources, developing countries would either develop less or would develop along traditional lines with great social and environmental costs, such as the increasingly predatory felling of tropical forests or the inefficient use of other natural resources such as fossil fuels. The correct application of CDM projects allows development together with the adoption of the best available technologies, thus 'leapfrogging' the unsustainable and wasteful path of development followed in the past by today's industrialized countries.

The Montreal Conference

The Kyoto Protocol only entered into force in early 2005. The period between 1997 and 2005 was therefore a very uncertain one for the Protocol and the different Conferences of the Parties that took place in this period were dedicated to discussing details of the application of the 'flexibility mechanisms' built into the Kyoto Protocol and the issue of afforestation. Since there are now only seven years remaining before the Kyoto Protocol expires in 2012, it is necessary to extend its commitments beyond 2012, or to adopt a new protocol that will not necessarily be an extension of the present. This was foreseen in 1997 and the Kyoto Protocol determined that the issue should be on the agenda in 2005. This is the reason why the Conference of the Parties in Montreal in late 2005 was important and signaled a new direction to the debate on how to face the challenges of climate change.

The Montreal Conference was in reality a superposition of two conferences: COP 11 (the Eleventh Conference of the 189 Parties to the Climate Change Framework Convention, including the United States) and MOP 1 (the First Meeting of the Parties that ratified the Kyoto Protocol, which do not include the United States).

The aim of these two events was quite clear:

- to extend the Kyoto Protocol beyond 2012 for the countries that ratified it;
- and to increase the number of countries agreeing to targets and timetables for GHG emission reductions, including not only the United States but also large developing countries (such as China, India and Brazil).

The first item on the Agenda was partially tackled. The Conference of the Parties "serving as the Meeting of the Parties to the Kyoto Protocol" adopted the following resolutions:

1. Decides to initiate a process to consider further commitments for Parties included in Annex I for the period beyond 2012;
2. Decides further that the process shall begin without delay and shall be conducted in an open-ended ad hoc working group of Parties to the Kyoto Protocol, thereby established;
3. Agrees that the group shall aim to complete its work and have its results adopted by the Conference of the Parties (serving as the meeting of the Parties to the Kyoto Protocol) as early as possible and in time to ensure that there is no gap between the first and second commitment periods;
4. Agrees further that this group will meet for the first time in 2006 and that subsequent meetings will be scheduled, as necessary, by the group;
5. Invites Parties to submit to the Secretariat, by 15 march 2006, their views on further commitments after 2012;
6. Agreed to discuss a compliance regime for the Protocol by electing a compliance committee with enforcement and facilitative branches, to ensure that the parties to the Protocol have a clear accountability regime in meeting their emission reductions targets.

The second item on the Agenda, which was basically to encourage the United States and large developing countries to adopt emission reduction commitments, led to a watered down decision to "engage in a *dialogue* on long-term cooperative action to address climate change by enhancing implementation of the Convention", the main points of which are:

a) Advancing development goals in a sustainable way;

b) Addressing action on adaptation;

c) Realizing the full potential of technology;

d) Realizing the full potential of market-based opportunities;

This dialogue will take the form of an open and non-binding exchange of views, information and ideas in support of enhanced implementation of the Convention, and "will not open any negotiations leading to new commitments", which is a rather weak statement.

An important novelty however was the adoption of an item on "voluntary commitments" by developing countries. The resolution adopted states that:

"The dialogue should identify approaches which would support, and provide the enabling conditions for, actions put forward *voluntarily* by developing countries that promote local sustainable development and mitigate climate change in a manner appropriate to national circumstances, including concrete actions to enable countries, in particular developing countries, to manage and adapt to climate change."

In this Resolution no distinction is made between different developing countries, despite the fact that only a few of them are significant emitters (emerging countries with very strong economies).

The decisions adopted in Montreal, although rather vague, are very timely because large developing countries such as China, India and Brazil – which have not accepted commitments to reduce or moderate emissions in the Kyoto Protocol – have recently become very large emitters of GHGs: today China is responsible for 17% of total CO_2 emissions (second to the US with 23%) and will probably surpass the United States in 10 or 15 years. The fact that China and other developing countries were exempt from emissions limits, something viewed initially as a way to avoid hampering their development, in fact had the perverse effect of justifying the refusal of the United States to accept any limits.

Brazilian deforestation area (2002) was multiplied by the net amount of carbon emissions per area of forest 102 tCeq/ha; according to the National Communication.).

Other non-Annex I: considered (1) annual forest cover change (1000 ha) from FAO;

(2) country-specific wood biomass in forests (tons/ha), also from FAO; (3) multiplied by a factor of 0.5 (IPCC default).

There will therefore be a flurry of meetings and workshops on the issue, and a report on the dialogue and on the information and diversity of views presented by Parties will be presented to the COP 12 (November 2006) and COP 13 (December 2007) sessions of the Conference of the Parties. The initial views of the Parties on the issues to be discussed in this dialogue should be submitted no later than April 15 2006.

Probably the most important item to discuss in the near future is how to deal with "voluntary commitments". An example of this is the issue of "avoided deforestation" proposed by Papua New Guinea and other countries, which was supported by Brazil. Figure I indicates the yearly rate of deforestation in the Amazon.

The issue is an old one because the deforestation of all tropical forests is responsible for approximately 20% of current GHG emissions, as a result of the clearing of some 100 000 sq km of virgin forest per year (one fifth of it in Brazil's Amazon region). Reducing deforestation to 75 000 sq km would avoid emissions of 250 million tons of carbon per year, which is equivalent to all the reductions established by the Kyoto Protocol. The proposal of Papua New Guinea and others is that industrialized countries would in some way compensate the developing countries in which deforestation is reduced.

Such activities cannot be based on handouts to keep impoverished populations living in forested areas from cutting down the forest in order to sell the wood – which has already proved to be impractical – but must create new employment opportunities by either using the products of natural forests sustainably, or through localized mining and ecotourism, where feasible. A tremendous amount of work lies ahead to identify such options, if they exist.

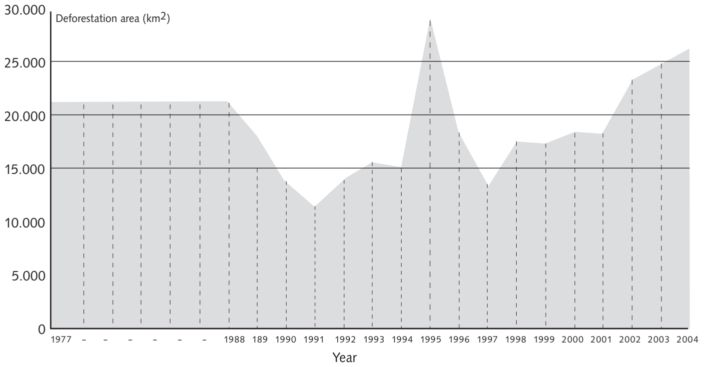
The change in posture of the Brazilian government in Montreal can be considered an important step because it could open the way to discussions on

Fig. 1 **Major GHG emitters in the world including deforestation (or afforestation) Top 10 Emission Countries, 2002**

Country	Fossil fuels	Change and forestry	Total emissions
	(Gg Ceq) 2002	(Gg Ceq) 2002	(Gg Ceq) 2002
United States of America	1,891,244	(188,379)	1,702,865
China	761,586	(160,461)	601,125
Brazil	83,930	382,002	465,932
Russian Federation*	391,664	(11,995)	379,669
Japan	362,944	(267)	362,677
India*	323,281	(3,376)	319,905
Germany	276,716	3,793	280,509
Canada	199,421	(5,630)	193,790
Indonesia*	73,572	116,570	190,142
United Kingdom	173,143	519	173,662

Notes: Data for fuel combustion from Marland et al. (2003). Non-Annex I countries, base year 2000. Land use change and forestry (LUCF): UNFCCC, 2005 (Annex I countries) and FAO, 2003 (non-Annex I countries, base year 2000). Brazilian LUCF data: National Communication (base year 1990) and INPE (deforestation area).

Fig. 1 **Gross deforestation rate of Amazon Forest**



other "voluntary commitments", which could in time become significant and, if properly monitored, as effective as binding commitments. Another example of other commitments is the elimination of flaring oil wells in many developing countries, capturing the gas (mainly methane) and using it for productive purposes.

The sticking point is that such projects were discussed in Montreal under the Climate Convention umbrella and not in the Kyoto Protocol. What this means is that they cannot benefit from the Clean Development Mechanism because it would be difficult to demonstrate their additionality, which is one of the requirements of article 12 of the Protocol.

An idea of the magnitude of the problem may be acquired by pointing out that reducing deforestation in tropical forests by 25 000 sq km would be equivalent in terms of avoided carbon emissions (at US$ 10/ton) to 2.5 billion dollars, which could in principle be the object of CDM transactions. That course of action was not accepted in Montreal. A solution outside of the Kyoto Protocol could be to encourage other productive activities that do not imply the destruction of the forest. If properly designed, they could require far fewer resources than the value of the avoided carbon emissions.

New resources would have to be found for that to be possible, which is rather problematic. The issue is nothing new. In 1991 the G7 (the group of rich-

Reconciling development and emission limits

Interview with **Harald Winkler.**

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What is the basic thrust of the Sustainable Development Policies and Measures (SD-PAMs) approach?

Harald Winkler: This approach, which is embedded in the Climate Convention that came into force in 1994, aims to reconcile economic development needs in developing countries (DCs) with limits on their greenhouse gas (GHG) emissions. It is based on the premise that implementing sustainable development policies plays a greater part in limiting GHG emissions than conventional development policies, and thus redefines priorities in countries that are generally more concerned with basic development needs than with climate change: instead of laying down emission reduction targets, it aims to build climate policies around these development priorities.

The SD-PAMs approach is therefore a means of making the development objectives of each country the basis, if not the substitute, for its climate policy. An energy development plan may be based on fossil resources or renewable energies. In some cases, the difference between the two technologies may be insignificant at the national level; there may however be a very considerable difference in terms of their impact on the climate.

In practical terms, how can this approach be implemented?

H. W.: This is a central proposal that can be varied according to the possibilities provided by domestic policies. Lasting climate protection measures can be implemented in many different development sectors: transport, energy, housing, etc. In South Africa, for example, the government has implemented a strategy to improve energy efficiency in industry by 12% by 2014. With the Reconstruction and Development Programme, South Africa also plans to build two to three million new houses. Many of these houses are currently built in a very basic manner: significant energy savings can be made by working on insulation, the size of windows or even the direction the houses face. These are the types of measures that might be framed as SD-PAMs.

Is there a standard protocol for implementing this approach?

H.W.: Implementing SD-PAMs involves several stages. The country first outlines its development objectives and, where possible, quantifies the expected benefits and potential risks. The next step is to identify the types of policies and measures that could make the pathway to this development more sustainable, based on existing but insufficient policies or new measures. These different measures must be recorded in a national registry to ensure a control system is able to monitor their implementation. Next, the impact on GHG emissions must be quantified in order to identify the measures that would lead to both the greatest benefits in terms of sustainable development and the greatest potential for reducing GHG emissions.

Could you list some emblematic projects?

H.W.: A recent World Resources Institute report[a], presented at the Conference of the Parties in Montreal, describes the applicability of SD-PAMs and presents four case studies on climate measures: the use of biofuels for transport in Brazil; urban transport efficiency in China; the different options for rural electrification in India; and carbon capture and storage in South Africa.

How can this approach be formalized in a future international climate change regime?

H.W.: This is in fact one of the questions we are asking ourselves: how can an approach based on national policies and measures be formalized and defined at the international level in a future climate est industrialized countries), alarmed by the rate of deforestation taking place in Brazil's Amazon region, offered 1.5 billion dollars to promote actions that would reduce such deforestation. The proposal was not well received by the Federal Government because of concerns that it would ultimately lead to a loss of national sovereignty over that area. The offer was then transformed into a complex World Bank project and reduced in size to 250 million dollars, which has so far been only partially implemented.

Outside CDM transactions, which involve the private sector, the only fund available for concessional grants is the Global Environment Facility (GEF), which is overburdened by supporting all kinds of programs, from biodiversity to desertification and climate change. The GEF receives, from all donors, approximately 1 billion dollars per year, which is insufficient for large projects for avoiding deforestation.

A solution could be to strengthen the Global Environment Facility or to establish a new fund for that specific purpose, and the new round of negotiations starting now should look carefully at those options. Clearly there would be no great enthusiasm from Annex I countries to fund strong emerging economies, which should in any case be more proactive in reducing GHG emissions, but concentrate on helping the least developed countries.

Another possibility would be to broaden the Clean Development Mechanism. This Mechanism implies the adoption of targets, on a project-by-project basis. It would thus be desirable to consolidate and enlarge the present regime, maintaining its advantages. The key to progress is to define the types of targets that are convenient for developing countries. Reductions should also not be relative to a level corresponding to a given year, but rather to the emissions projected for the future. Without reduction targets there is no carbon market, and without a carbon market there will be no resources from the industrialized countries. In addition, the future regime could improve upon the present regime by reducing the complexity and the costs of the present system.

There are several options, including sectoral targets that do not cover the entire economy. For exam-

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change agreement? In other words, what mechanisms must be set up in order to achieve formal recognition of the different types of SD-PAMs possible? Here again, several stages may be envisaged. First, the international community must agree on a general framework for what makes an SD-PAM eligible in terms of commitments made under the UNFCCC. Second, a process must be set up allowing parties to the Convention to define the pledges to be made for each of the different SD-PAMs, whether unilateral, mutual or harmonized multilateral pledges. Third, once pledges have been made, these SD-PAMs could be registered and monitored by the Secretariat of the Convention. Fourth, a broader program for measuring progress would be necessary, including a peer review mechanism. Finally, although this approach is essentially qualitative, it must be given a quantitative dimension and could be integrated into the emerging emissions market. Thus, the existing framework of the Climate Convention could guarantee the monitoring of these voluntary initiatives and make them more binding, without this requiring a new protocol.

Does this approach constitute an official position of the South African government?

H.W.: Not really: above all it is an approach based on South African scientific research[b]. Of course we have discussed it with the authorities of the country and South African climate change strategy gives priority to sustainable development. But the SD-PAMs approach as it stands is not an official national position.

Furthermore, it is not really a position to defend in negotiations; it is more a starting point for launching initiatives and mobilizing funds for sustainable development in DCs. This approach is not exclusive and can be combined with others. It is of interest to many other developing and emerging countries, including India.

There are several advantages to this approach: it takes full account of national circumstances and helps give DCs the confidence to take part in a global climate change framework. However, it also presents two major disadvantages. First, it does not guarantee a global reduction in GHG emissions, since rather than a reduction from 1990 levels – as with the Kyoto Protocol – it implies reducing emissions in relation to business-as-usual projections. Second, it is analytically difficult to measure the net impact of a basket of SD-PAMs on GHG reduction.

How acceptable is this approach?

H.W.: According to interviews carried out by NGOs in South Africa, it appears that the SD-PAMs approach is a welcome step forward for sustainable development. But at the same time, they stress that this approach cannot be merely a provisional tool given that it does not represent a global policy for reducing GHG emissions. The private sector has shown its interest in this point: it finds it simpler to refer to a sustainable development framework than to precise environmental targets. Companies prefer to be associated with the circulation and implementation of technical solutions than to be subject to emissions limits.

Interview by Damien Conaré

a « Growing in the Greenhouse: Policies and Measures for Sustainable Development while Protecting the Climate », WRI, 2005. http://climate.wri.org/pubs_description.cfm?PubID=4087

b « Sustainable Development policies and measures: tackling climate change from a development perspective », Harald Winkler, Randall Spalding-Fecher, Stanford Mwakasonda, Ogunlade Davidson, WRI, 2002 ple if Brazil decides to double its Alcohol Program by 2015, it will be contributing to reducing global carbon emissions by 10 million tons of carbon per year; with PROINFA, a renewable energy program for electricity generation, an additional 3 million tons of reductions per year will be achieved. If deforestation in the Amazon region were to be reduced by 10%, 20 million tons of carbon per year would cease to be emitted. This could be the object of a World Bank structural project that would contribute to the sustainability of development in the Amazon. The commitments would be voluntary, but they would result from a negotiation in which the other main actors – including the US – would also put on the table their contributions to the emission reductions, which are in fact happening in several U.S. states, such as in California. China is also making serious technical progress in the coal-fired electricity generation, resulting in emission reductions without affecting their economic growth.

The possibility of reconciling voluntary commitments with the Clean Development Mechanism was not excluded in Montreal, with the further guidance to the CDM adopted, in the rather obscure style that follows: "a local/regional/national policy or standard cannot be considered as a clean development mechanism project activity, *but that project activities under a programme of activities* can be registered as a single clean development mechanism project activity provided that approved baseline and monitoring methodologies are used that, inter alia, define the appropriate boundary, avoid double-counting and account for leakage, ensuring that the emission reductions are real, measurable and verifiable, and additional to any that would occur in the absence of the project activity.

It was also recognized "that large-scale project activities under the Clean Development Mechanism can be bundled if they are validated and registered as one clean development mechanism project activity and invites the Executive Board to provide further clarification if needed".

If properly implemented, these resolutions would open the way for a new regime that would in fact include developing countries, removing the main argument of the United States to stay out of a compromise of accepting binding targets for reductions in the GHG emissions.

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The United States, which refused to comply with the Kyoto commitments, seems to be in the process of adopting mandatory domestic regulations. The European Union, which committed to similar targets under the Protocol, is having difficulties to meet them. Analysis of these paradoxical developments highlights the shortcomings of the international climate change regime and, seen from across the Atlantic, leads to calls for a less universal regime with greater flexibility and more incentives.

An American "point of view"

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Since June 2005, there have been a number of climate policy developments in the United States suggesting that the possibility of mandatory, federal regulation of greenhouse gas emissions in the next few years is becoming more likely. Such an event would alter the dynamics of international negotiations over future climate regimes, returning the United States to a position where it could engage the international community in a meaningful way and, equally importantly, create an opportunity for the international community to move forward inclusive of the world's largest emitter and wealthiest country.

At the same time these developments are occurring in the United States, we find that the Kyoto Protocol is now nearly a decade old, and there is a great deal of new information available about both how climate policies work and how countries go about implementing such policies – information that could constructively influence the shape and feel of a new regime. We have, for example, observed that an international regime is neither necessary nor sufficient for domestic action. This is particularly true in the United States, where any indication of international influence on domestic policy frequently has a countervailing effect. We have also seen that effort tends to be a more natural point of convergence for national action than emission levels. Despite the Kyoto Protocol's focus on emission quantities, policy proposals have tended to be more aligned on emission prices, where prices are somewhat synonymous with effort. We have seen that concern over international action (or inaction) tends to focus on a small number of countries, either large economies or large emitters. And we have begun to recognize the complex challenges surrounding technology development and developing country engagement – challenges that are not easily met by simple market-based policies alone.

From these observations in the United States and abroad, we can draw at least five conclusions about how a future climate regime might usefully diverge from the existing Kyoto Protocol. First, there needs to be much greater deference to domestic interests – whether it is concern about excessive reliance on natural gas in the United States or an overwhelming priority on economic development in countries like China and India. There needs to be recognition of national differences in policy preferences – countries may pursue taxes, tradable permits, standards, regulation, or some combination of all of the above. Second, international efforts need not focus on all countries, especially in the beginning. The potential for meaningful mitigation and concerns over competitiveness are limited, in most cases, to a small number of countries. Engaging in dialogues with those countries is likely to be more effective than seeking consensus among the nearly 200 countries participating in the U.N. process. Third, the regime needs to include technology development and investment activities (technology push), not just mitigation (demand pull). Fourth, efforts to engage developing countries need to proceed at all levels – project-based credits, sectoral or policy-based credits, and broader linkage with other issues such as energy security and trade. Finally, the emphasis needs to be more clearly on evaluating actions after the fact, rather than agreeing on targets and timetables in advance of any action.

If this latter suggestion seems relatively "squishy" compared to the elegance of legally-binding commitments under the Kyoto Protocol, consider this: The Bonn and Marrakech agreements in 2001 literally renegotiated the Protocol targets four years after they were set (Russia, for example, received an additional

130 million tons in sink credits). The exit of the United States from the Protocol that same year further left the remaining participants with only a marginal aggregate commitment – if the Russian Federation and Ukraine sell their excess emission rights (a.k.a. "hot air") under the Protocol to Europe, Japan and Canada, those countries would be required to do very little. Finally, the Clean Development Mechanism has the potential to flood the market with cheap credits – or not – depending on how the rules evolve. The question is not whether an agreement is squishy, but how and when.

The remainder of this paper reviews recent policy developments both in and outside of the United States, and then draws conclusions about the implication for future climate regimes. The important thread throughout the discussion is that what we observe happening -- in public policy debates, in government proposals and decisions, and in responses to domestic action (or inaction) -- all of this should inform the design of a future climate regime. This "practical" approach to thinking about the regime, and what it needs to accomplish given real world observations, stands in contrast to an idealized approach that imagines what we think would be best, based on some notion of welfare or well-being, and typically absent any constraints. While it is useful to continue thinking about such an ideal as a guidepost for the long-run climate regime, a rigid focus on that ideal will inevitably miss opportunities – perhaps significant opportunities – to improve cooperation in the near term.

Recent developments in the United States

Given the role of the United States as the world's largest emitter, wealthiest country, and key holdout from the Kyoto Protocol, any practical future regime will need to expend some effort to accommodate U.S. policy. Since 2002, the basis of U.S. climate policy at the federal level, articulated by President Bush, has been voluntary efforts to achieve emission reductions through 2012 (White House 2002). Over the subsequent four years, however, the president's position has spurred a number of actions, at the state level and in Congress, that not only suggest a building momentum for mandatory federal action, but also provide information about the kind of U.S. policy a global regime will likely need to accommodate.

Beginning at the state level, there is long history of initiatives to address issues like renewable energy and energy efficiency. Twenty states and Washington, DC now have minimum renewable energy standards (UCS 2006). California and a number of other states have also pursued end-use efficiency programs since the mid-1970s (Rosenfeld 1999). More recent developments specifically surrounding climate change have focused on vehicle emission standards in California and tradable emission limits in the northeastern states.

California's effort began in 2002, when the legislature passed, and the governor signed, A.B. 1493 authorizing the California Air Resources Board (CARB) to establish greenhouse gas emission standards for light-duty vehicles. Under the U.S. Clean Air Act, California uniquely has the authority to set different vehicle emissions standards than the federal government (owing to its air quality problems). Other states then have the option of adopting California standards. In 2004, CARB finished its rulemaking and called for a 30% reduction in emissions per mile (essentially equivalent to a 30% improvement in fuel economy) by 2016 (CARB 2004). Since then, other states including New York have adopted the same standards. Currently, the Alliance of Automobile Manufacturers is suing CARB over whether this is really a fuel economy standard in disguise, for which California would not have the authority to set a different standard (Meltz 2006). If the standards are upheld, they would begin to go into effect in 2009.

Perhaps more significant among state efforts is the initiative of a group of northeastern states to establish a regional trading program for power plant emissions of carbon dioxide, the Regional Greenhouse Gas Initiative (RGGI). Initially nine states negotiated the agreement, including New York, New Jersey, Connecticut, Delaware, Massachusetts, Rhode Island, New Hampshire, Vermont, and Maine. The proposed caps would limit emissions to 2005 levels through 2015, followed by a gradual decline (RGGI Staff Working Group 2005). More relevant than the proposed caps, however, are innovative features that offer possible lessons for a federal program: a required 25% auction, new approaches to offsets, and consideration of future linkages (Kruger and Pizer 2006). While seven states signed a memorandum of understanding in December 2005, with the governors of Massachusetts and Rhode Island declining to join, the legislatures in Maryland (formerly not even part of the RGGI group) and Massachusetts recently passed laws requiring their states to join.

It is against this backdrop of burgeoning state-level action that the U.S. Senate has increasingly become the focal point of federal policy discussions. Beginning as far back as 1997, when it unanimously passed the Byrd-Hagel resolution, the Senate has regularly been engaged in the climate change policy debate. In particular, that 1997 resolution stipulating that the United States would not join an international agreement without meaningful participation of developing countries, and if the agreement would harm the U.S. economy, was and continues to be a defining feature of U.S. rhetoric. More recently, in 2003, the Senate rejected – by a vote of 55-43 – a proposal by Senators McCain (R-AZ) and Lieberman (D-CT) to create an emissions trading program focused on year 2000 emission levels. Despite the fact that its rejection can be viewed as consistent with the Byrd-

Hagel sentiment, the vote was, at the time, viewed as something of a victory for environmental advocates – seemingly only 7 votes shy of passing the proposal versus the unanimous Byrd-Hagel vote (Senator Edwards (D-NC) missed the vote but presumably would have voted in favor).

In June 2005, during a series of debates over climate amendments to the 2005 Energy Policy Act, a slightly modified version of the proposal garnered only 38 votes, at first glance suggesting a downward trend in support. Yet, that moment may eventually be viewed as an important turning point in the climate change policy debate. During that same hectic period, an alternative proposal by the ranking member of the Senate Energy Committee, Senator Bingaman (D-NM), based on the recommendations of the National Commission on Energy Policy (NCEP 2004) was filed but not voted on. That resolution was rumored to have generated interest from Senator Domenici (R-NM), chairman of the committee, who eventually declined to support it. Instead, the two Senators from New Mexico agreed to hold a series of hearings on the issue. And, not to leave its position ambiguous, the Senate passed, 54-43, a resolution calling for mandatory climate change regulation that, in contrast to the Byrd-Hagel resolution, stipulated developing country *engagement* and avoiding *significant* costs to the economy (versus *meaningful participation* of developing countries and *harm* to the economy). Perhaps even more remarkably, the same non-binding resolution recently (in May 2006) passed the House Appropriation Committee as a rider on an appropriations bill – though it was almost immediately stripped from the bill on procedural grounds (Berman, 2006).

Since the votes last summer, Bingaman and Domenici have followed through with their commitment to a series of hearings, with the tone of these hearings becoming increasingly detailed. The first two hearings discussed climate change science and economics at a fairly high level of abstraction. However, in February 2006, the senators published a white paper posing a series of detailed questions about (1) the appropriate point of regulation in a mandatory emissions GHG trading program; (2) the method of allocation of GHG permits; (3) the design of offset programs; and (4) possible linkages with programs in other countries. Stakeholders and analysts were encouraged to respond to the questions and, after 140 separate respondents had filed submissions, the senators held a hearing in April 2006 with 29 of those respondents testifying. Most of the witnesses had very detailed responses to the questions, and many referenced the threat of a patchwork of state-level policies, of the sort just described, as a reason to seriously consider pre-emptively enacting federal policy. Senator Feinstein used the hearing as an opportunity to announce yet another Senate proposal, this one focusing on generous provisions to farmers and the agricultural community.

There are three notable trends reflected in these latter developments. The first is that Domenici and Bingaman appear settled on some of the large design features of a mandatory program based on the NCEP proposal. That is, an intensity-based growth cap that eventually seeks to limit economy-wide emission to roughly 2013-2014 levels. A key feature of the proposal is a $7 per ton of CO_2 safety valve, meaning that businesses are assured that compliance costs will not exceed that price, though with the consequence that emissions may not achieve the cap. This assurance of a cost limit has been a significant factor in the decision of many businesses and conservatives to embrace or at least seriously consider the proposal. Equally important has been the acknowledgement that mitigation policy alone is not the solution: it must be accompanied by a strong technology program focused on both research and development, as well as commercialization. The Bingaman proposal and the underlying NCEP recommendation explicitly fund significant new investments in clean coal, capture and sequestration, nuclear, renewables and biofuels (for power generation and transport), vehicle efficiency (including diesel and hybrids), and more general efficiency for buildings and industry. A final feature of the Bingaman-Domenici formula is an explicit recognition that after the United States acts, it will periodically look back at the actions of other countries – key competitors and major emitters – and adjust U.S. policy accordingly.

The second element is that Domenici and Bingaman are now engaging, quite substantively, in the very detailed implementation questions that remain obstacles to progress (after the aforementioned agreement on large design features). As recent experience with National Allocation Plans in Europe has demonstrated, allocation is a particularly difficult issue. Another challenging issue is where to regulate and who to include. These topics were the primary focus of the white paper and hearings, and continue to be particularly important in the U.S. policy debate (in this regard, it is notable that Massachusetts' recent legislative effort to join RGGI called for movement towards a 100% auction).

The third trend, parallel to the preceding one, is that companies are now becoming engaged at a serious and high level in thinking about what they believe a mandatory program ought to look like. Companies are hiring analysts, sponsoring studies, and contemplating both the possibility of regulation in the United States and their role in shaping it. The very detailed responses to the white paper, as well as the fact that many other companies found themselves unprepared to address the questions, have spurred what appears to be a much broader deliberation among U.S. businesses.

While this Bingaman legislation (or one of the competing proposals) is far from a done deal, there is a growing sense that forces are converging towards U.S. action. State action is putting pressure on federal lawmakers. The Senate is passing resolutions calling for mandatory actions, holding detailed hearings, and, most importantly, finding some of its more conservative members engaged on the issue. Even the House appears to be interested in the debate.

Yet, all of these developments are transpiring almost without regard to action in other countries and without regard to a future international regime. The fact that the Bingaman proposal, for example, is not compatible with the targets and mechanisms in the Kyoto Protocol, or with the EU Emissions Trading Scheme (ETS), is of almost no concern to policymakers. In fact, any sense that the international community is trying to influence U.S. domestic policy often results in a backlash against the effort. Ironically, these same policymakers *are* concerned that other key countries quickly initiate climate change policies comparable to proposed U.S. action, once that U.S. action occurs. The Bingaman proposal specifically includes a look-back provision, noted above, requiring periodic review of national actions in other countries and consequent adjustment of U.S. policy in response. Therefore as we think about future regimes, even from a U.S. perspective, we need to review developments in other countries.

Climate policy outside the United States

One of the most interesting and revealing features surrounding climate change policy around the world is the range of domestic responses that have been implemented or proposed. This is true despite the legally-binding commitments to quantitative, economy-wide targets made by industrialized (Annex B) parties the Kyoto Protocol; targets that in turn suggest specific, cap-based national policy responses. Among Kyoto parties, four countries (or groups of countries), in particular, are worth looking at because of the variety of their policies or proposed policies: the European Union, New Zealand, Canada, and Japan. It is also worth discussing progress with developing countries, as major emitters and trade competitors such as China and India continue to be a focal point for those concerned about both emissions and costs.

Chief among domestic climate policies is the EU Emissions Trading Scheme (ETS). With the exception of a few, limited, carbon tax programs in certain EU countries prior to 2003, the EU ETS is the first example of mandatory climate change mitigation policy in effect in the world. It stipulates an absolute cap on covered sources, which include the power sector and several energy intensive industries (refining, paper, etc.) – roughly 50 percent of total EU-wide emissions. This cap, allocated to each covered source, can be freely traded among sources creating an EU-wide market for emission reductions.

Like the NO_x program in the United States, member states in the EU are responsible for allocating allowances within their borders. Unlike the U.S. program, however, member states are also responsible for setting their overall cap level as well. National allocation plans (NAPs) – including both the overall cap level and allocation to sources – are proposed and then approved by the EU Commission. Importantly, NAPs must convey how limits on member-state sources within the ETS, coupled with other national actions for non-ETS sources, will achieve the country's Kyoto commitment. So far, we have only seen NAPs that deviate slightly from business-as-usual, remaining far from those Kyoto commitments in many member states. The real test will arise later in 2006, when member states submit plans for the actual Kyoto compliance period 2008-2012. Plans for the initial, warm-up phase, 2005-2007, presumably were subject to more lenient interpretations[a].

At the other end of the spectrum of mandatory policies, New Zealand was on track until December 2005 to implement a CO_2 tax that would have started in 2007. The government announced, in 2002, that they would implement an economy-wide carbon tax that would approximate the international price of emissions, but be no more than NZ$25 per ton CO_2. Energy-intensive industries that faced international competition would be allowed to enter agreements to avoid the tax, and agricultural methane and nitrous oxide (which accounts for more than half of total NZ GHG emissions) would be excluded entirely (Hodgson 2005, 2002). The initial level of the tax was to have been NZ$15 per ton CO_2.

Japan similarly considered a carbon tax during internal government discussions, at a level of ¥2,500-3,000 per ton of carbon (e.g., $6-7 per ton CO_2), but did not put a proposal forward as an official government position. Instead, Japan has pursued a primarily voluntary, incentive approach based on initiatives by the Keidanren (business associations), "top-runner" efficiency standards, and, more recently, a voluntary trading program and up front payment for credits through the Clean Development Mechanism (Pizer and Tamura 2005). The latter two efforts, along with a mandatory reporting program, form the Kyoto Target Achievement Plan, approved by the cabinet in 2005 to reduce Japan's emissions by the estimated 6% necessary to meet its Kyoto commitments.

In the middle sits Canada. Canada announced plans for a Large Final Emitter (LFE) trading program in April 2005 for the oil and gas, thermal electricity, mining and manufacturing sectors. The program is based on intensity targets; that is, the emission limit for firms is indexed to industry output. Further, the program has a C$15 per ton CO_2 safety valve. Like the Bingaman proposal, Canadian firms can always buy extra allowances in the domestic program at C$15 to meet the target, thereby providing a cost cap to firms. Of course, this does not comport well with the Kyoto Protocol, which includes neither an index to output, nor a safety valve. However, it does represent a compromise – perhaps a necessary compromise

– between industry taking on a mandatory emission program while leaving the government responsible for meeting the specifics of the Kyoto Protocol. In any case, concerns about the LFE comporting with Kyoto have been dwarfed by concerns that Canada will not even implement the LFE program. In March 2006, after the government changed parties, the environment minister indicated in a letter to a Toronto newspaper that emissions trading *may* be part of an *eventual* strategy to reduce greenhouse gas emissions (Ambrose 2006).

Meanwhile, virtually all major countries with emission commitments under the Kyoto Protocol, as well as firms with domestic commitments under existing or proposed national policies, are engaged in project-based efforts located in developing countries. The World Bank is now managing nearly $1 billion in various project funds for different countries. Natsource, a brokerage firm, recently capitalized more than $500 million in private funds to purchase credits. A similar fund in Japan recently collected $150 million in private funds.

Despite this large interest on the demand side, there is considerable controversy about whether this approach – and specifically the Clean Development Mechanism – is working on the supply side. While slow to ramp up, as of April 2006 there were 161 registered projects, 4.5 million issued credits, and 340 million credits slated to be issued from registered projects through 2012 (UNFCCC 2006). There are more than a billion more credits associated with other CDM projects in some phase of design. For reference, the *annual* surplus (e.g. extra allowances above what they need) expected in Russia and Ukraine is about 840 million tons (Babiker et al. 2002) and total U.S. emissions are about 7 billion tons per year. The CDM is therefore a large supply, but not so large compared to Russian supplies. What is also remarkable about the supply of CDM credits is the make-up: Roughly half are HFC23 projects; another sixth N_2O. That leaves about a third as energy-related projects (Victor 2006). Whether these metrics suggest modest success, or not, is somewhat in the eyes of the beholder[b]. Critics say this is too little action in the wrong sectors, or point to the inherent problem of establishing baselines for individual projects; proponents say this is just the beginning.

Meanwhile, the larger Kyoto model for developing countries – that they will eventually graduate to emission commitments – is being challenged despite promises of generous allocations or side payments. The problem is that developing countries may not see accepting a limit on their carbon dioxide emissions – essentially their use of fossil fuels – as a reasonable trade-off at any price[c]. Equally important, there is also a limit to the willingness of industrialized countries to pay a high price to developing countries for participation, perhaps even more so if it is paid in a very decentralized way (versus subsidizing technologies produced by the industrialized countries themselves). At the end of the day, if developing countries become sufficiently concerned about climate change, some arrangement should be possible. However, the question for a future climate regime is, what do we do in the mean time?

Implications for future climate regimes

There are two immediate observations from this brief survey of actual and proposed policies. The first is that Kyoto parties are pursuing a variety of policies that are only loosely connected to their commitments. Even the European Union, with its trading program, cannot be confident it will achieve its target given that 50% of its emissions remain outside of the program. Estimates by the European Environmental Agency suggest that compliance will depend on additional measures as well as decisions about the use of Kyoto flexibility mechanisms (EEA 2005). Other countries such as Canada, Japan, and New Zealand face even greater challenges given the absence of any mandatory programs so far. The second immediate observation is that momentum appears to building for mandatory action in the United States *despite* any international commitment, while the European Union actually made its decision to implement the ETS *before* it was certain the Kyoto Protocol would come into force.

The implication of these observations seems to be that binding international commitments are neither necessary nor sufficient for domestic actions in the near term. Countries face a variety of domestic constraints and pressures that trump international pressure in shaping policy. The form of a New Zealand policy is undoubtedly shaped by the relative share of agricultural emissions in their inventory. In the U.S., comments on the Bingaman-Domenici white paper were surprisingly favorable to an upstream program – something that has been eschewed in Europe (an upstream program would regulate *producers* of fossil fuels rather than *users*). Meanwhile, we have seen evidence that voluntary programs in some parts of the world – particularly vehicle efficiency standards in Europe and Japan – may work.

Further, the notion of binding commitments poses particular hurdles in the United States. As noted earlier, international constraints on domestic policy are typically unwelcome. From a legal standpoint, there is the additional problem that the U.S. typically does not ratify a treaty unless there is legislation in place that assures compliance (CRS 2001). The bottom line, as many scholars have noted, is that international treaties are inherently voluntary from the perspective of sovereign countries, making binding commitments something of an illusion (Barrett 2003).

Under these circumstances, it seems that the most useful feature of a future climate regime may be support and encouragement for a wider variety of domestic actions. While there may be an evolution over time towards specific emission commitments, an explicit sharing of responsibility, and common architecture, such developments probably need to come *after* nations first explore their own domestic capacity, resolve, constraints, and circumstances. Much like nuclear disarmament, the World Trade Organization, and the European Union – all of which evolved from simpler beginnings as experience with, and trust in, partners and institutions grew – the same is likely to be the case with a global climate regime.

Another lesson that can be borrowed from the latter two examples of evolving international institutions is that both started with a smaller number of like-minded countries and expanded in numbers over time. Climate change lends itself naturally to this approach because a relatively small number of countries are responsible for the overwhelming volume of greenhouse gas emissions. Those same countries are also the ones typically viewed as competitive threats to business. In the United States, the focus is typically on Europe, Canada, Mexico, Japan, China, and India. Meanwhile, a fully global negotiating process run by consensus – like the United Nations – is easily sidetracked by other nations with special interests and little to contribute.

A smaller process, including the abovementioned nations and a few others, was recently proposed by the previous Canadian Prime Minister Paul Martin under the guise of an "L-20" forum, referring to the leaders of 20 key countries (Martin 2005). He argues that this type of forum could be used to deal with issues where political leadership is necessary to move the world forward, such as climate change, just as the G-20 forum of finance ministers has been used to deal with economic issues. The idea has also been posed by scholars similarly struck by the asymmetry of influence and responsibility in the U.N. process and the need for bottom-up developments among key countries (Victor *et al.* 2005). Finally, one need only look at the implementation of domestic policies to note that most exclude sources below a certain threshold; it is therefore somewhat remarkable that we have approached climate change with the idea of including *all* sources – achieving consensus among *all* U.N. nations.

Therefore, a second suggestion for a future regime would be a narrower focus on key emitters and economic powers. This same focus is articulated in the Bingaman proposal and could work alongside the U.N. process rather than replace it.

In addition to a more flexible approach to commitments and participation, the question of substance remains. While much of the review of domestic policy initiatives focused on mandatory regulations, there is a growing recognition that mitigation policy alone will not deliver desired technology developments, and that there is a trade-off to be managed between near-term mitigation and long-term technology development. The U.S., in particular, has emphasized technology policy and the Bingaman proposal, while mandatory, includes a significant technology component. Economic literature also points out that there are two market failures surrounding climate change – the externality associated with emissions, and the broader underincentive to innovate because the returns on innovation are difficult for the innovator to capture – therefore requiring two policy instruments to achieve an efficient outcome (Fischer and Newell 2004). Equally or more importantly, there may be political limits on the capacity to properly price the emission externality, adding to the importance of technology policies that are often welcomed by industry (as more of a carrot than a stick). Finally, there may well be commitment problems with pricing policy alone that technology policy can circumvent (Montgomery and Smith 2005).

All of this points to the importance of a future regime that recognizes the role of technology investments alongside mitigation efforts. Such a feature will likely broaden the appeal of the climate regime (Barrett 2001; Carraro and Buchner 2004). But more importantly, it better matches the features of the problem, which are fundamentally about technologies that can eventually move the world's energy system to a zero-emission, concentration-stabilizing world. Recent experience with the EU ETS, for example, has put a high premium on near-term targets coupled with considerable uncertainty about future commitments, as prices have spiked to $30 per ton CO_2. Such a situation may be inefficiently diverting resources towards short-term, crisis efforts to meet a target rather than steady, sustained efforts to find long-term technology solutions.

After a more flexible architecture, a narrower focus on key countries, and an explicit recognition of the mitigation-technology policy balance, a fourth component of a future regime needs to engage developing countries – and do so on as many levels as possible. This follows from the observation that developing countries have, so far, been unwilling to embrace emissions trading with industrialized countries, even with offers of side payments or generous allowance allocations[d]. Even if they were convinced, their capacity to implement market-based policies is suspect (Bell and Russell 2002). It also follows from the observation that, with global trading, unquestionably the largest source of cheap reductions would be developing countries – meaning they cannot be ignored. So, until both their interest and capacity match that of the industrialized countries, we need to consider practical policies that will reduce emissions in developing countries as cost-effectively as possible.

Based on the earlier discussion surrounding the CDM, it seems prudent to consider more avenues to engage developing countries. Two proposals were discussed at the recent COP / MOP meetings: sector-based crediting and credit for deforestation. In the current environment, both have the capacity to inject a large number of credits into the system and may represent too much supply. In the longer-term, however, I believe they represent two of three useful directions. That is, first, there needs to be a willingness to encourage developing country policy reforms at the sectoral level. Whether we are talking about efficiency standards, energy market reform, or other carbon-saving initiatives in developing countries, there should be incentives on the table. This might be a package of sector-based credits, or it might be linked to progress in other areas of national interest (e.g., trade or technology). Second, there needs to be a more flexible approach to project crediting that moves away from ton-for-ton accounting. Credit for deforestation is one idea, but the broader approach would be to standardize projects that are desirable, ideally (but not necessarily) keeping the right incentive at the margin. For new technologies where there are likely to be learning spillovers, or for projects with other co-benefits, the incentive could be higher. The finicky approach to baselines in the CDM needs to be replaced with a more streamlined, though perhaps not as environmentally-pure, approach.

Finally, Victor (2006) also makes the point that even more than projects and sectoral policies, major infrastructure deals have the potential to dramatically alter emission trajectories. If Russia, for example, could be encouraged to pipe gas to China, the potential emission reductions from less coal use in China could match the reductions attributable to the entire EU ETS over the next decade. Such deals are unlikely to happen under a purely climate-focused initiative, but approaching major developing countries about such choices, and looking for ways to tie them to issues of greater concern – economic development, security, or conventional pollution – ought to be a key element of an effort to engage developing countries.

As a final regime suggestion, given the broader parameters for countries joining such a regime on the front end, it will be important to include mechanisms to evaluate actions on the back end. In other words, as we encourage countries to make more flexible, non-legally binding commitments initially (relative to the Kyoto Protocol), we should focus our energy instead on a clear commitment to evaluate what actually happens after the fact. Bodansky et al (2004) refer to this as a policy and measures approach (or sometimes, pledge and review). Here, measures describe both the steps to be taken, as well as the metrics for evaluating action. This is the basic model for cooperation conveyed in the look-back provision of the Bingaman proposal.

An interesting observation from the various policies that were summarized earlier is that all have tended to converge in *effort* as reflected in the price placed on carbon dioxide. Table 1 summarizes the prices associated with various proposed and actual climate policies. While not exhaustive, it shows that there has been a remarkable convergence among prices, reflecting effort (at least at the margin). Autarkic prices upward of $50 per ton of CO_2 and varying by more than $50-100 across country, predicted by most models in order to comply with the Kyoto Protocol (Weyant and Hill 1999), have not occurred – suggesting that despite treaty commitments focused on emissions, a more natural point of agreement may be prices. While there has been a tendency not to want to put a price on environmental concerns, especially during environmental negotiations, economic interests and a focus on effort appears to play a greater role when domestic policy is enacted. Moving forward, it may be necessary to admit this reality and focus the evaluation more clearly on prices and effort, rather than solely on emissions and environmental outcomes.

Conclusions

The starting point for a future climate regime needs to be the experience gleaned over the decade since the creation of the Kyoto Protocol. Part of this is experience with the United States – where binding commitments have proven to be especially problematic – but much of this experience has occurred elsewhere as well. Ten years ago, the architects of the protocol had only economic theory, experience with various non-climate environmental policies, and dissatisfaction with outcomes arising from the UNFCCC, on which to build. They developed a global system based on legally-binding emission limits, flexibility mechanisms that leaned on market-based responses, the idea that domestic policies would evolve to meet the protocol's requirements, and the assumption that developing countries would graduate to industrialized countries' commitments. Much has been learned since then.

Most importantly, we have seen that domestic policies tend to evolve only partly in response to international commitments. Even in the European Union, where arguably the greatest synergy between the protocol and a domestic policy exists, it is not clear that their Kyoto commitments will be met. No other Kyoto party has even adopted mandatory climate change regulations, and even those that have been proposed are less congruent to the Kyoto architecture than EU policy. Meanwhile, events in the United States suggest that mandatory domestic controls may occur sooner than previously thought – even without a binding commitment under the Kyoto Protocol. Legally binding commitments, it turns out, are also at odds with the U.S. approach to treaty law. All of this suggests that a future regime needs to be flexible in embracing a wider range of domestic policy responses, and less rigid in terms of attempting to impose international constraints, than the Kyoto Protocol.

A second conclusion is that a future regime should focus initially on the world's largest emitters and economies, rather than attempting to immediately implement a global solution. Experience with other significant global issues – trade, monetary union, and arms control – suggests dealing with key, like-minded nations first. Experts ranging from academics to leading politicians have suggested that climate change, especially, requires such an approach. Finally, rhetoric in countries like the United States has repeatedly emphasized concern over competitiveness with key trading partners, suggesting the relevant universe for U.S. engagement is limited to a much smaller number of countries than the UNFCCC. All of these arguments support the idea of pursuing negotiations among a small group of countries, perhaps in parallel and as a complement to continued UNFCCC work.

Aside from these suggestions for shape and form, two substantive issues deserve particular attention within the design of a future climate regime. The first is recognition of the balance between efforts on near-term mitigation and long-term technology development. Economic theory concerning market-failures in the market for innovation and arguments about the time consistency of policies that only price emissions both point to the need for technology policies to complement market-based incentives to reduce emissions. This also aligns with political difficulties achieving prices liable to spur innovation – particularly in the United States, but also likely elsewhere. While the Kyoto Protocol focused almost exclusively on near-term targets, a future regime should have a longer-term view – not just on targets but also on technology development. To do this, there needs to be an acknowledgement that technology policies have an important role, even as a high value is placed on mandatory efforts to begin limiting emissions.

The second substantive issue is a broader and more flexible engagement of developing countries. The Kyoto model focused on project-based crediting with the idea that developing countries would graduate to the cap-like commitments of industrialized countries. The emerging reality is that such a future is neither being embraced by developing countries, nor arguably practical given institutional constraints. Further, project-based crediting alone faces significant limitations. Therefore, a future regime could constructively consider at least three additional avenues for engagement: policy or sector-based crediting, a relaxation of strict ton-for-ton accounting in order to encourage a wider variety of actions, and a deal-based approach to major development, security, and conventional pollution projects with significant carbon-saving consequences.

Finally, all of this needs to be rolled together with a more extensive program to evaluate national actions after the fact. This kind of feedback on existing policy and actions can replace the up front negotiation of targets in order to help countries stay synchronized with each other's level of effort, as well as to provide a forum for countries to challenge each other toward stronger actions.

In summary, a future climate regime based on the practical experience of the past ten years is likely to look considerably different than the current Kyoto Protocol. Such a regime could usefully involve more flexible commitments, a smaller number of initial participants, increased attention to technology, broader engagement of developing countries, and explicit efforts to evaluate national policies and actions after they are implemented. These changes also reflect the arguable trend in U.S. policymaking, as evidenced by a recent proposal by Senator Bingaman and based on work by the National Commission on Energy Policy. In this way, there is a real possibility that action in the United States, the European Union, and elsewhere, could gradually converge under a common agreement in the coming years.

FIG. 1 **Summary of prices**

Program	Price/tCO_2	Price US$/$tCO_2$	Notes
EU Emissions Trading Scheme	€15-25	20-30	Trading range in 2006
Canada LFE program*	CA$15	13	Safety-valve price
New Zealand tax*	NZ$15	9	Initial rate
Japan tax*	¥2,500-3,000	6-7	Proposed rate
Bingaman (U.S.)*	US$7/$tCO_2$	7	Safety-valve price
McCain-Lieberman (U.S.)*	US$15-30/$tCO_2$	15-30	Estimated price**

*Proposed
**Paltsev et al (2003) and EIA (2004).

a More information can be found at http://europa.eu.int/comm/environment/climat/emission.htm.

b In a recent workshop, both perspectives were heard. See http://www.weathervane.rff.org/process_and_players/Policy_Collaboration/Understanding_Translatlantic_Differences.cfm.

c There is a useful analogy to the plight of coal mines and mineworkers. Plenty of studies have shown that it would be relatively cheap to pay them to shut down (Bovenberg and Goulder 2002). Yet, in conversations with mining companies and mineworkers, they are less than enthusiastic about giving up their business and way of life in exchange for a government promise of its cash value. Similarly, developing countries may be reluctant to give up the tried and true approach to economic growth – freely burning fossil fuels – in exchange for industrialized country promises of allowance revenues or side payments.

d See description, for example, of developing country reaction to discussions of the second Kyoto commitment period at the COP/MOP-1 in Aguilar et al (2005).

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