ENERGEX 2000, GLOBEX 2000

ENERGY AND ECONOMICS:

"MOVING BACKWARDS TO THE FUTURE"

1) Understanding the past
2) Meeting the challenges of today
3) Squaring the circle of forecasting
4) Keeping all energy options open

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LAS VEGAS, JULY 2000

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I. UNDERSTANDING THE PAST

It was a very dark night in Paris and there was this man looking for something under the halo of a streetlight.

- *"Hey man, what are you looking for?" I asked him.*
- *"My car keys" he grumbled.*
- *"Are you sure you lost them here?" I then said.*
- *"No", he answered, "but this is the only place with some light!"*

What data for what purpose?

I am like this man. I know that the problems lay somewhere in the future but the only light is that of the past. This is why one has to examine and understand what the past reveals about the respective roles of GDP (Gross Domestic Product), energy efficiency, energy shocks and end-user prices on energy demand, and what the features of the different primary energies are. Yet, before starting, one has first to agree on some common plain language and on the same understanding of words such as GDP, energy efficiency or energy demand.

Measuring economic wealth.

Even without considering the question of economic "externalities" that energy creates because of the insecurity of supply, the degradation of environment or the depletion of exhaustible resources, the measurement of GDP raises a number of methodological problems: is GDP the right indicator of economic wealth? What common currency should be used to aggregate GDPs of different countries? How reliable GDP estimates are?

Measuring GDP is not easy. In the early 90s, some initial US GDP growth rate estimates had to be revised downwards because they were based on the assumption that no more economies of scale were to be expected for IT equipment whereas the later evidence showed that costs, prices and values added were still in decline. If such an error can affect the largest economy in the world, what to say about the un-assessed "grey" or "black" economy in many countries, or for some inflated figures in centrally planned economies? The accuracy of GDP estimates is at doubt and necessarily limits our methodological ambitions. In a similar vein, GDP includes exported goods and services but does not include imports. Should trade imbalances exist for many years in a row, e.g. with some countries over consuming (as it was often the case for the USA) and others under-consuming during these periods of time, GDP may not represent the overall economic consumption and it may be preferable to consider broader regions (e.g. the set of market economies or the set of economies in transition) because of their lesser degree of external opening.

In the least developed countries, the exchange rate of the national currency only partly reflects the purchasing power of the currency. It also incorporates the political risk associated to this country. As a general rule, the lowest the level of economic development, the highest the corresponding political risk and currency under-valuation. Furthermore, some developing countries have implemented low exchange rate policies in order to enhance their international competitiveness. Overall, the difference between GDP at official exchange rates or purchasing power parities (ppp) rates is quite large according to CEPII[4]'s estimates: in 1999, the GDP of the developed market economies was about 20T$[5] (at both official and ppp rates) that of the other countries was about 5 T$ with official exchange rates (see graph 1) and 15 T$ with ppp rates (see graph 2). This reveals the importance of using ppp rates if one wants to avoid the distortions that official exchange rates create.

The case of the economies in "transition" (former Soviet "Empire" and its satellites, China) is further complicated because their statistical system is recent, of poor quality, sometimes flawed (there are many anecdotes reported by the official newspapers, such as these ponds which, after being dried, still produce fish!) and often methodologically biased. The former concept of net material product, that ignored services and only measured actual quantities (rather than the corresponding added values, as for GDP), is still strongly embodied in the way of thinking of these countries. How can one believe that such a broad country as China, of which half the economic system (that of the large state-owned enterprises) is inefficient and nearly bankrupted, could grow by more than 10% a year with its energy consumption only growing by 5% and grew recently by about 7% with energy consumption drawing back? Economic distortions in the economies in transition are so large that these countries should be studied in isolation and not be aggregated with the market economies.

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[4] A French official body « Centre d'Etudes Prospectives et d'Informations Internationales » which is associated with the French Planning Commission.

[5] In this paper, I use the International System units with k (kilo) for thousand, M (mega) for million, G (giga) for billion and T (tera) for trillion. Hence, T$ stands for Teradollars i.e. millions of millions dollars.

Measuring energy consumption

"Energy consumption" is an ambiguous concept. It can be the total primary energy requirements i.e., the sum of traditional fuels (that include combustible renewables and wastes), fossil fuels, large hydro, other modern new renewables and nuclear. It can also be the final energy demand that gathers the three energy-related services (electricity, mobility and stationary combustible fuel end-uses). Sometimes it can be both when a country exports electricity: production will be accounted in primary energy equivalent whereas exports, even in the primary energy balance, will be accounted in final energy (this is the case for the French nuclear electricity exports). Lastly, it is both a quantity expressed in kWh, Joules, MBtu, etc, and a qualitative concept related to the convenience of a specific fuel or the level of comfort that its use provides.

In this paper, the different primary fuels are measured in a consistent way by assuming that the "theoretical" efficiencies of all new renewables, hydro and nuclear are identical and close to the actual efficiency of fossil fuels power plants, i.e. 40% according to Total's convention (the one used in this paper), close to the 38.46% figure used by WEC for their book "Energy for Tomorrow's World: Acting Now", and unlike IEA's conventions (100% for hydro, solar and wind, 10% for geothermal, and about 40% for nuclear) because of the inconsistencies they create, e.g. suggesting that Brazil is more energy efficient because of its sizeable hydropower share.

Because GDP includes exports and does not include imports, the apparent energy consumption does not reflect the actual consumption. It does not include the energy embodied in imports nor excludes that embodied in exports. The bias is not negligible in an open and global economy. Many developed market economies import a growing share of their steel, aluminium or fertilizers consumption from countries that have competitive advantages because of their cheap energy (South America, Norway, Middle East, Russia, Korea, Australia, etc.). Hence, energy consumption has become a diffuse notion which only makes sense if one considers closed economic regions with no or little trade with the rest of the world, say for the market economies their whole set or the three regions of the "Triad" (Americas, Western Europe/Africa/Middle East, Asia/Pacific) and for the economies in transition, their whole set or each of the two former blocks ("iron" and "bamboo" curtains).

Measuring energy intensity

Two issues are of particular relevance, the process of economic development with the progressive substitution of non-commercial energy (human, animal and biomass energy) by commercial energy (fossil fuels in the early stages followed by the penetration of electricity) and the process of "de-location" of energy-intensive activities from countries with high energy prices to those with cheap energy prices.

While the energy series I use in this paper incorporate some recent estimates of non-commercial combustible renewables and wastes (CRWs) thanks to the IEA, there are no estimates of the energy provided by human and animal force. Their total amount is small, a few hundreds Mtoe, but may be an important share of the energy supply of some very poor countries. In the process of economic development, the progressive substitution of such unaccounted energy by new commercial energy for transport, agriculture and heating purposes increases the corresponding energy intensity. That explains why, apparently, energy efficiency does not improve in the developing countries as much as it does in the developed countries.

In a world economy that becomes global thanks to the lowering of customs barriers, the rise of energy prices following the oil shocks has been the revealing factor, if not the motor, of the de-location of energy-intensive activities. Three periods are worth examining, 1974-79, 1980-85 and 1986 onwards:

- During the 74-79 period, developing countries got two competitive advantages in addition to their cheap labour: energy (for the producing countries or those having good sea logistics such as Brazil and Korea) and capital (because of the recycling of the "petrodollars"). Hence their decision to launch major industrial infrastructures, that, because of the lead times to build them, came only on stream after 1979.
- During the 80-85 period, there was a coincidence between the coming on stream of these new state-of-the-art units in the developing countries and the unfavourable economic environment in the developed countries (recession and high energy prices) causing the closure of a number of uncompetitive idle plants. This two-fold process gave the impression that these latter plants were physically de-located, i.e. replaced by the new plants of the developing countries.
- Because the lead time of such major investments is about 6 years, the bulk of the process of "de-location" described in the previous paragraphs has come to an end in 1986, six years after 1980, beginning of the second oil shock recession and end of the heavy investment period. Since 1986, it only exists at a much lesser extent, mostly for some energy intensive industries such as steel, aluminium or petrochemicals.

The drivers of energy demand

By order of importance, energy demand depends on GDP, end-user prices and climate. Conversely, as it will be discussed further in this paper, one may wonder if energy efficiency policies do impact the level of energy demand, even though they may have a real impact on the quality of service energy provides.

The role of GDP ppp[6]

We have introduced two major methodological breakthroughs (described in the following paragraphs and figures), which are now used by Total, the IEA and the WEC:

- **The first breakthrough is the introduction of a new x-scale, GDP ppp instead of time.** As can be seen on the following graphs, the role of GDP becomes much clearer with such a scale. Unless prices or climate conditions change, energy demand evolves in a regular, nearly linear, manner with GDP.
- **The second breakthrough is the introduction of the concept of energy-related services, namely electricity, mobility and stationary combustible fuel end-uses.** It avoids two drawbacks, that of aggregating the final demands of electricity and fossil fuels (what equivalence should be used? is there a single equivalence for different electricity uses?) and that of splitting the industrial and commercial sectors (industry does not provide "goods" anymore since they are progressively replaced by "packages" which incorporate both a "goods" and a "service" components).

Furthermore, as previously mentioned, the aggregation of all, developed and developing, market economies cancels out the differences between the high "embodied" energy of imported industrial goods into developed countries and the lesser one of exported services to the developing countries.

Graphs 3, total primary energy, and 4, final energy-related services, represent the energy demand of the market economies (all countries in the world excluding the economies in transition of the former Soviet Union, Eastern and Central Europe, and China[7]). Primary energy is measured according to Total's conventions with the actual input of fossil-fuels power plants and, for hydro, nuclear and all new modern renewables used in power generation, an input corresponding to a "theoretical" 40% efficiency. In addition, we have included non-commercial combustible renewables and wastes (IEA statistics which are similar to those of the WEC).

Primary energy grows by about 2.5% when the GDP grows by 3%. In other words, the progressive improvement of the productivity of all economic inputs (say capital, labour and energy) when GDP grows is reflected in the smaller than unity marginal energy intensity. This 0.83 marginal intensity of energy demand to GDP is nothing else than the so-called "Autonomous Energy Efficiency Improvement" (AEEI or "free lunch factor") described and used by Alan Manne (Stanford University). It reflects the productivity improvement as well as the corresponding structural evolution of energy consumption when GDP grows. Electricity grows faster than GDP (1.1 elasticity), mostly at the expense of combustible fuels in stationary end uses (0.6 elasticity after 0.75 before the shocks and 0.67 between the shocks). Transport, which was growing faster than the GDP up to the end of the 70s, is now growing at the same pace (1.0 elasticity).

The two following graphs, 5 and 6, show the split of the market economies between the developed market economies (US and Canada in North America, Western Europe excluding Turkey and former Yugoslavia but including Iceland, and, in the Pacific area, Japan, Australia and New Zealand) and the developing market economies (all the other countries excluding the economies in transition). They show different behaviours, partly complementary. The energy to GDP marginal elasticity of the former group is smaller (about 0.65 corresponding to a 2% energy growth for a 3% GDP increase). That of the developing countries is larger (about 1.0 with a 1% to 1% match between energy demand growth and GDP ppp increase). The difference may be partly explained by the industrial "de-location" (see the acceleration of demand in the developing countries at the time of the second oil shock which is, to a certain extent, symmetrical to the energy fall in the developed countries) and partly by the apparition, in the developing countries, of new commercial energy demand which replace some former unaccounted human, animal or biomass energy uses. Another possible explanation lies in the weak improvement of the productivity of the factors in many fast developing countries (e.g. in Asian countries where most of the GDP growth is attributed to the growth of the economic inputs[8] and not to rapid productivity increases).

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[6] See my paper « Le lien entre consommation d'énergie et développement économique », Revue de l'Energie, n° 515, March-April 2000.

[7] There are some other small centrally planned economies, namely RD of Korea, Vietnam, etc. Their weight is small and I have chosen, in this paper, to leave them with the developing market economies of Asia.

[8] See "The Return of Depression Economics" by Paul Krugman, W. W. Norton & Company, Inc., New York, 1999. In chapter 2, the author provides several comments about the low growth of the productivity of the factors in the Asian countries

In the economies in transition (graphs 7 for the former "Iron curtain" block and 8 for China), trends are disturbed because of unreliable GDP estimates, changes of energy pricing or payments, and possible statistical errors in energy production. Nevertheless, in the former Soviet block, 1989 shows the beginning of the restructuring and the drop of both GDP and energy demand, a process that, today, seems to come to an end. Similarly, in China, the impact of the 1978 economic reforms by Deng Xiao Ping is clear as well as the impact of the Asian crisis combined with the beginning of internal reforms in 1997.

<u>The role of final prices</u>

End-user price is the second most important driver of energy demand. In the developed market economies, the disruptions of the trends of primary energy demand or related-energy services clearly show the importance of prices. A closer look at the energy-related services brings more information:

- The most sensitive demand is that of combustible fuels for stationary end uses, mostly in industry because of the absence of price absorber. Fossil fuels used in the industrial sector being not much or not taxed at all, industry felt the full impact of the price rises, even more when uncompetitive plants became idle because of the economic recession.
- Transport demand in the US was hardly affected by the first oil shock because the oil quota put in place by President Eisenhower in 1959 isolated the US oil pricing system from the international oil market However, demand fell strongly at the time of the second oil shock because its timing coincided with the liberalisation of the US oil prices.
- In the other regions of the world, the combination of thick mattresses of taxes and fixed costs, rapid inflations and small short term price elasticities explains why transport demand was not noticeably reduced by the oil shocks;
- Electricity demand evolved in a constant manner. Final prices have remained the same in constant money throughout the whole 1960-2000 period, even at the time of the oil shocks, because of the small weight of oil prices (vs. large variable and fixed costs in power generation, transport and distribution) and the control of States on Utilities (limited tariff increases to avoid to push inflation further up).

In short, there are three different price responses to an oil shock. Firstly, an immediate (say within a few months) small short term price elasticity, say –0.1 or less. Secondly a two years energy drop because of short term adaptations (e.g. instalment of some insulation or heat-exchangers including some closures of inefficient idle plants) which coincides with the drop of economic growth because of the change of productivity of economic inputs, and the indirect macro-economic impact of inflation and interest rates rises. Thirdly, the decision to launch new infrastructure and capital stock investment that will come on stream after six or more years

NB In an economy in equilibrium, all economic "factors" or "inputs", say labour, capital and energy, have the same marginal economic productivity (the value brought by the investment of one additional dollar is the same whatever the factor in which it is invested). If the cost of energy rises, the economic productivity of energy is lowered in the same proportion and becomes lower than that of the other economic factors. The return to a new economic optimum will combine a lesser use of energy (energy savings) to increase its marginal productivity from the low level it has reached, and an increase use of the more efficient factors, namely labour and capital, at the expense of a decline of their marginal productivity. In short, one will be back to a new equilibrium with the same marginal economic productivity for all factors, yet at a level lower than what it was prior to the energy price rise. These are the mechanisms at work after the first oil shock of October 1973 (economic slow-down of 1974-75), after the second "twin" oil shock (double price rise of April 1979 and September 1980 resulting in the combined slow-down of 1980-81-82). The symmetrical effect, i.e. a productivity rise, took place after the early 1986 counter oil shock, and resulted in the economic growth acceleration of 1987-88.

Since the obvious price impacts only take place within the two years following a "shock" or "counter-shock", i.e. the time needed to adjust the macroeconomics, change a boiler, add some energy saving equipment, or close a plant which has become uncompetitive, one cannot easily measure the long term impacts of a higher energy price environment, i.e. the change of the energy trend after the shock (lower trend or slope or both?). However, the comparison of the energy intensities of different countries with different energy price environments is quite instructive. In graph 9, I chose to display electricity intensities because (see earlier comments) electricity is the only fuel with a more or less a constant level of price within each country for the whole period. This is also the reason why economies in transition were not taken for this crosscutting comparison: prices or payment systems are neither reliable nor constant during the period. This graph, courtesy of the IEA, shows that the many points, each one associated with a country, draw an hyperbolic shape with a long term price elasticity close to –1.0 as if consumers of different countries were trying to spend the same share of their budget whatever the level of price. This graph confirms the importance of the level of end-user prices in the long run.

The role of climate and weather

The decline of the share of stationary fossil fuel end uses when GDP grows suggests that the impact of climate is smaller when GDP is higher. Two reasons may be called upon: the growth of domestic energy consumptions which are not climate-related (all the more so as electricity consumptions, from that of the toaster to that of the computer, have a warming contribution and reduce the heating needs in the cold countries which are the majority of the developed market economies) and the increasingly enhanced performance of the buildings, specially in the countries with very cold climates such as Canada, Finland, Sweden, to name only the most impressive examples. In fact, it seems that the same level of final energy prices leads to energy consumptions more similar than the intrinsic warming needs are.

However, there is no way to adapt to random and short-term climate variations. This is why annual variations of degree-days will result in small increases or decreases of energy consumptions. This is what happened during the 1990 decade, the warmest of the century (and according to the French Historian Le Roy Ladurie, the warmest of the millennium), especially in 1990, 1997 and 1998. Whether 1999 will or not correct this departure from the long run is not known yet.

Impact of energy efficiency policies

The invisible hand

On the average, consumers seem to base their energy consumption on their income and energy price, the two most important drivers of energy demand. Some consumers "over-optimise", some "under-optimise" their energy consumption but there is no reason to suspect a systematic bias in favour or disfavour of energy. This is why the many individual behaviours add up, for each country and each energy-related service, in a global trend that seems to accurately and consistently over time reflect the true level of price, including its shadow elements introduced by regulation and constraints. This level of energy consumption corresponds to a marginal economic productivity of energy equal to those of the other economic factors, labour, capital, raw materials, etc. In short, millions of individual behaviours sum up as if an "invisible hand", that of the price signal, was leading them.

If policy-makers and their advisors were truly convinced that energy prices and only energy prices (the level of GDP is not a variable of command) matter, they would ensure that, firstly, the prices reflect all the energy costs, direct or indirect (identified externalities) and, secondly, the price signals work their way transparently to all consumers (in particular, everybody should pay the price). Yet, in practise, the evidences are quite different from this ideal attitude:

- Firstly, average energy prices are no more cost-reflective today than they were in the past. At an aggregated level, the only price changes are those brought by the price shocks and, to a much lesser extent, by the counter-shock. Many private (e.g. company cars) or public (e.g. the coal support in countries like Germany) energy subsidies still exist or have even increased during the last 30 years at the expense of the improvements brought by cost-reflective pricing and payments in other sectors (e.g. the instalment of individual heating meters in collective buildings). Even though energy security and environmental concerns have grown since thirty years (with clear and rising indications of their negative impacts) they are not reflected in the prices.
- Secondly, given the stability of energy trends out of the shock periods, energy efficiency policies aimed at correcting market "failures", at increasing transparency of energy choices and at improving consumer awareness do not seem to have quantitative impacts in terms of lesser energy consumption. Either market inefficiencies do not exist or they are so deeply rooted in our societies that they cannot be removed. In other words, either the consumers pay their energy bill, are well aware of its costs and behave rationally without government intervention, or they do not pay it for whatever reason and government policies have failed to address the problem.
- Thirdly, public money spent for increasing energy efficiency was not necessarily wasted. Since energy efficiency improves autonomously along with the GDP growth and its associated productivity increase (a process revealed by the smaller than one marginal energy intensity), policies that actually increase GDP growth do also promote energy efficiency. Furthermore, the quality of the energy service provided by one unit of energy has possibly increased. In that respect, I regret that so little is done to measure this qualitative impact brought over time in terms of comfort, convenience or well-being by better buildings, larger homes (maybe with "cathedral" ceiling), safer and better air-conditioned cars, increasingly sophisticated domestic appliances, etc.

Wishful thinking or reality?

In the early 80s, A. Lovins said: "The long term supply curve for electricity is as flat as the Kansas horizon". Did he moved to Colorado, not far from Boulder, because the rising perspective of Rocky Mountains outcrops is a more appropriate setting to describe the future of electricity demand ?

Green advocates and many civil servants in charge of energy efficiency policies have a tendency to consider that the only good energy is saved and that any energy consumed is wasted. Energy-related service trends say a different message: energy consumptions are consistent with the level of prices. Therefore, the only relevant questions for the policy makers are:

- Whether prices are cost-reflective (including identified security or environment "externalities"). This question was recently (1999) debated in the WEO (World Energy Outlook) series of the IEA for a number of developing countries. But one can also ask it for many developed countries, including the USA, given the number of EPA studies about the under-pricing of gasoline.
- Whether energy prices are paid. While this question seems to mostly address the developing countries or the economies in transition, it is worth to ask it in our rich countries, for instance in the UK, world champion for the share of company cars but certainly not alone in its category.
- Whether consumers get the best benefit out of their energy consumptions. To my knowledge, this matter is not addressed and there is no attempt to measure, at a given level of energy consumption, the increase of welfare brought by better cars, buildings, appliances… and the shortfall of welfare that market failures (e.g. the tenant- landlord dilemma[9]) create.

The conclusion one can draw from 30 years of energy efficiency policies is that, for a given price, the expectation that increased energy efficiency lower consumptions demonstrates a total lack of understanding of the way an economy operates. The more efficient energy use is, the more energy will be used. Coal demand exploded at the time of the industrial revolution because more cheap coal was available thanks to the combination of the enormous efficiency increase brought by the steam engine, the use of coal to fuel it, and their joint development to pump water out of the deepest, yet most prolific, coal mines. Conversely, it is a pity when energy efficiency does not reach the end user: a consumer with a less than optimum efficient car will run less miles with less comfort and a tenant of an under-insulated condo will get less heating or cooling comfort than with an optimum design and construction. Taking energy consumption as the only criterion may lead policy makers to ill-targeted decisions whereas a serious look at the qualitative aspects would permit, for a chosen energy price and its corresponding energy consumption, to maximize the welfare level.

[9] In order to save money, a landlord may build a cheap poorly-insulated building which will provide less comfort in terms of heating or air-conditioning to the tenant. This may also increase the running costs of the tenant if the overall energy consumption is larger that it would be with a state-of-the-art building. The overall welfare of the landlord and tenant will not be optimised.

II. MEETING THE CHALLENGES OF TODAY

Structural reforms and the E-revolution might favour rapid productivity improvements and better economic growth prospects in spite of the aging and greying of the world population. However, these better prospects have to be matched with a number of growing constraints, namely the finite capacity of the atmosphere to absorb increasing concentrations of greenhouse gases (GHG), the scarcity of natural resources (oil outside the Middle East, natural gas in North America) and the growing macroeconomic imbalances in a number of key regions of the world. In the following paragraphs we shall concentrate on the energy sector.

Structural reforms

For energy, the most striking reforms of the two last decades are the liberalisation, sometimes together with the privatisation, of the gas and electricity industry. While the two industries need to move at the same pace given the key role played by combined cycle gas turbines (CCGTs) for the new electricity generation capacities, the experience so far has been of an industry lagging the other because liberalisation is often a trial and error process in which the experience gained from gas is then extrapolated to electricity or vice-versa. A key and growing aspect of liberalisation is to what extent the consumer is really "empowered" thanks to the benefit of competition or whether the former monopolies are to re-appear because of the growing concentration that the economies of scale and scope favour.

The case of natural gas

The oldest world gas market and industry are those of the US and it is here that the process of liberalisation started in 1978 with the Natural Gas Policy Act (NGPA). The progressive freeing of the well-head gas price and the "rolling-in" allowance (which permitted to blend "new" deregulated gas with "old" still regulated gas at their weighted average price) had a quite dramatic effect: a surge of gas production (with prices up to 10 US$/Mbtu for some new gas) at the time when demand was plunging because of economic recession, higher prices and "de-location" of some gas-intensive industries. This created an enormous overhang (the so-called gas "bubble") of excess supply commitments that became unsustainable when the oil counter-shock precipitated the fall of the prices. The bargain which then took place under the auspices of the Federal Administration (and subject to a number of legal litigations) was the removal of part or totality of the liabilities of the gas companies (which, up to that time, were both merchant, i.e. aggregators and sellers of gas, and gas transport, i.e. pipelines, companies) in exchange of the opening of their pipelines to allow third party access.

This was extremely successful with the creation of a versatile competitive market in which the difference between the prices of gas at two different locations genuinely reflects the cost of transportation (low when capacity is idle, high when capacity bottlenecks appear), and the difference of price at different periods reflect the complex interplay between supply, storage and marginal demand. As in most competitive markets, gas price is set against the marginal demand, namely a floor determined by Texas' "imported" coal, i.e. that which flows on the Mississippi river from the Northern States to the power-plants of the South, at about 1.2 US$/Mbtu and a ceiling determined by the price of low-sulphur fuel oil which can be used against gas in the large industrial or power-plants boilers of the North-East (Chicago to New-York).

A large part of this success stems from the particular conditions of the US gas situation that exist nowhere else, in particular the existence of many different pipelines competing against each other. If tariffs had only be set by the regulators, there is no doubt that, given the dissymmetry of information between the regulator and the gas companies, tariffs would have been higher than what they actually are. For instance, the progressive rise of overcapacities in a context of pipeline to pipeline competition led, at times, to actual transport costs (inferred from the comparison of gas prices in North-East and Henry Hub) as low as 0.20 $/Mbtu between South and North-East, as compared to official tariffs of about 0.70 US$/Mbtu,

In Europe, with the exception of the UK, the process of gas liberalisation is just starting now thanks to the EU gas directive and the competition created by the Channel "Interconnector". There is no doubt that prices, which up to now were weighted averages of the netbacks provided by the different customers (heavy fuel oil for the large interruptible industrial or power boilers, distillates for most of the captive customers, electricity for some limited uses such as cooking), will go down relatively to the oil prices but the process will be slower and less efficient than in the US because of the shelter provided by the EU directive for the already signed long term take-or-pay supply contracts and because the prospects of pipeline to pipeline competition are, unlike the US, absent or very limited.

Another European gas feature that, unlike North America but like the gas situation of Japan (where most of the LNG terminals are not inter-connected), could become a source of concern is the lack of physical interconnections among the different countries of Europe. Hence, given the high and growing dependence of Europe on imported gas, security of supply is lesser than what it could be in a fully integrated European gas market. The recent disruption of a large part of the Australian gas supply because of the failure of a single gas node should be a lesson for Europe and Japan because of their dependence on a few key infrastructures.

<u>The case of electricity</u>

The opening of the UK electricity sector to competition resulted in an enormous dash for gas with more than 20 GW of new CCGT or/and cogeneration facilities being built. However, this happened because of the UK specific circumstances but not because of competition:

- A first wave of base load CCGTs facilities was launched with long term and high gas price power supply agreements because during the early period of privatisation and opening to competition, the Regional Electricity Companies (which still had a monopoly for all their captive consumers) were allowed to build their own power plants to produce up to 20% of their total supply. Given the fact that they were in a position to sell this electricity whatever its cost, the high price of gas and the corresponding high electricity cost at the time was not a constraint.
- A second wave of CCGT investments took place when the price of gas fell (because the opening of the former British Gas monopoly freed a large natural gas surplus) while electricity prices were high (marginal pricing set by the coal-fired plants of the National-Power / Power-Gen duopoly). This came to an end when the government, after receiving the analysis of the IEA[10], made the decision to freeze the new orders of CCGTs and to increase the competition among the coal-fired plants, with the expectation that the opening of the Interconnector would raise the spot price of gas and the increased electricity mid-load competition would lower the spot price of electricity.

<u>Lessons for the future</u>

The cases of the US and UK bring a series of lessons about the benefits of competition and the risks of market power abuse in a physical network industry such as gas or electricity:

- The US gas market example will also probably apply to the electricity sector. It shows that the combination of gas-to-gas and pipeline-to-pipeline competition ensures that the consumer really enjoys a flexible, versatile and competitive market (even the unregulated “grey” market provides the extra flexibility of transmission pricing that tariff formula cannot bring).
- Conversely, the UK gas and electricity examples indicate what the potential problems are, namely the oligopolistic price setting during the periods of strong capacity demand and the risk that there might be too few actors to have a really competitive environment (because very large distribution companies enjoy competitive advantages thanks to their economies of scale and scope)

In a tight market, the number of competing plants in a given area shrinks because of the bottlenecks of the infrastructure. Such situations arise periodically in similar conditions and there is no doubt that the only or few companies involved will rapidly learn how to behave (e.g. by withdrawing some capacities) to increase their revenues. Such de-facto monopoly or oligopoly situations will generally not result from an explicit arrangement in infringement of the law but will be the natural consequence of a trial and error process of each participant given the attitudes of the others.

The economies of scale and scope may bring a specific energy dimension for the security of supply and the competition between different fuels at consumer level. The larger the supplier, the greater the capacity to smooth random perturbations and the cheaper the provision of security. Hence, a natural tendency to grow which might come at the expense of the choices offered to the consumer and, to avoid that to happen, the need for the government to intervene to avoid large concentrations. Similarly, should heat, natural gas and electricity be supplied by the same company, end-user choices may be distorted and the consumer stuck with a biased choice unless government intervene to ensure a level playing field.

Setting the right balance between the economic arguments of the companies and the democratic rights of the consumer to be “empowered” will hardly affect the future energy trends. However it is of uppermost importance because of the practical implications it has on the shape of the industrial actors.

[10] International Energy Agency, « The United Kingdom 1998 Review »

Environment.

The Kyoto protocol

The purpose of this analysis is not to discuss the political process of ratification nor the realism of the targets agreed in Kyoto. Even without ratifying the protocol, governments may face a growing public pressure, beyond the only "green" circles. Right or wrong, there are more and more comments in the media about the possible linkages with the intensity of phenomena such as El Nino, El Nina, catastrophic hurricanes or floods, the melting of the ice cap, etc. Hence, the energy industry which is responsible for 85% of the GHG emissions in the industrial countries (those which have made commitments in Kyoto in 1996) cannot ignore the risk that governments will require strong action and, should such actions been decided, need to be strongly involved.

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Share of Greenhouse Gases in Total GHG Emissions from Energy
Industrialised countries (Annex I countries)

Gas Type	CO_2	CH4	N2O	Others	S
Share in Total GHGs	82%	12%	4%	2%	100%
Contribution of Energy Sector	96%	35%	26%	n.a.	85%
Main Source of Energy Sector	Fuel combustion	Fugitive fuel	Fuel combustion	n.a.	

Source: UNFCCC, "Second compilation and synthesis of national communications", FCCC/CP/1998/11/Add.1, September 1998.

Annex I (industrialised[11]) countries consume about two thirds of the world commercial primary energy while the non-Annex I (developing) countries only consume one third. The decline of the carbon intensity of their total primary energy supply (graph 10) is bottoming out because most of their nuclear programmes are now frozen and the deep economic recession in the FSU and Central/Eastern European countries has come to an end.

Graphs 11 and 12 show the past trends of fossil fuel related carbon emissions in the developed market economies and industrialized economies in transition (80% of the total GHG emissions for these countries). In developed market economies (graph 11), the relationship is regular since 1982, only affected by the two warm years of 1990 and 1997 and the restructuring of East Germany since 1989. The year 1998 was the warmest on record since 1860, reinforcing the downward inflection, although 1999 was somewhat cooler due to the impact of La Niña. Overall, since 1990, reference date of the Kyoto protocol, carbon emissions have grown by about 30 MtC a year in these countries. In the industrialized economies in transition (graph 12), there has been an enormous drop since 1989 (about 60 MtC per year between 1989 and 1997), now coming to an end.

The Economics of Climate Change

The Kyoto Protocol involves issues of a political nature, but its economic implications are often overlooked, especially for the energy industry. If one recognises that there is at least some probability that climate change will require action (the so-called "precautionary principle"), the simple economic evidence is that the constraint put on man-made greenhouse emissions implies a "shadow cost" on such emissions, i.e. a negative value on each ton of carbon or carbon equivalent emitted into the atmosphere.

In reality very little is known about the "carbon value". The UNFCCC[12] has repeatedly said that lowering greenhouse gas emissions has a value that, unfortunately, they have been unable to quantify. Given the present uncertainty, the most one might say is that the carbon value today should be low, 20 $/tC[13], according to the World Bank, a value reflecting an uncertainty range of, say, 10 to 40 $/tC

[11] Developed market economies and industrialised economies in transition (Russia, Ukraine, Baltic republics, Central and Eastern European countries)
[12] United Nations Framework Convention on Climate Change
[13] As a rule of thumb, ten dollars per ton of carbon emitted in the atmosphere (10 $/tC) is equivalent to one dollar per barrel of oil.

This value should evolve over time in a way that guarantees that the overall cost of abating GHG emissions is minimum. Hence, the discounted value of abating one ton of carbon tomorrow should equal the value of abating it today with the corresponding discount rate incorporating the risk-free interest rate in constant money, about 3% per annum, the rate of decay of carbon in the atmosphere, about 1% per annum, and a risk premium reflecting the present level of uncertainty about the climate change threat and its progressive reduction over time, say 3% which makes a discount rate of 7%, i.e. a doubling of the carbon value every 10 years in constant dollars.

Non energy-related or non-carbon greenhouse gas emissions:

- Several AIJ projects (activities implemented jointly) over the 1990s have shown that there is a potential of very low cost abatement, e.g. forestry sinks or methane leaks, which is worth launching for carbon values as low as a few dollars per ton. However, even if the low-abatement-cost share of these gases were to be significant, it would still be a small amount as compared to the energy-related carbon emissions (energy-related carbon makes 80% whereas the other greenhouse gases make 20% only), therefore leaving most of the reduction burden to the energy industry.

Energy-related carbon greenhouse gas emissions:

- **Power generation.** This is by far the most sensitive sector to a carbon value and, within it, coal is the first target for reduction. Oil is not very sensitive to a carbon value as long as it is used for power peaks since, for peak use, fixed costs represent a large share of the total cost. Because of its lower storage cost, oil could even be favoured for mid-load uses to provide additional flexibility for natural gas used in the domestic sector for seasonal heating. For natural gas, the introduction of a carbon value enhances the competitiveness of CCGTs against other fossil fuels and only marginally lowers its present advantages against nuclear or renewables.
- **Stationary fossil fuel end use.** In industry, services and households, these are the second most sensitive energy service to a carbon value. A carbon value would accelerate the displacement of oil products by natural gas as long as new gas resources come on stream and enough seasonal storage is available. However, given the small GHG advantage of remote gas against oil as long as carbon values remain low, the effect would be small. Coal is already declining for heating needs, and its substitution by direct reduction or electrical processes in iron mills would only be accelerated.
- **Transportation.** It would be hardly affected by a low carbon value in most developed countries because of the already existing high taxes on gasoline and diesel, about 1000 $/tC for gasoline in Europe and Japan, slightly less for diesel. Even in the US where the level of taxes on gasoline and diesel is low (equivalent to about 200 $ per ton of carbon) the impact would be small. Gasoline or diesel price would only increase by 5 cents per gallon for a $20/tC, at best reducing the intensity of transportation per unit of GDP by a few per cents over the long run.
- **Final electricity.** Its demand is not sensitive to a carbon value, but a very large one, because of the high share of fixed costs and the possibility of fuel switching to reduce the variable costs.

<u>Implications for the Energy Industry</u>

Four general principles should be kept in mind regarding climate change policy:

- A carbon cost will lower economic growth, at least in the short term, because of the need to adjust capital stock. Hence the importance to set the cost right, at a low initial level, and to clearly indicate its likely increase over time.
- Abatement costs are the lowest for the coal-fired electricity because this sector is more sensitive to a carbon value than any other energy related service. Hence the need to act primarily on this sector[14] in both industrialized and developing countries.
- Capital stock turnover is key because cleaner technologies are always cheaper at the outset than at the later stage of refurbishment aimed at cleaning existing plants. This is the reason why international policies should primarily aim the developing countries where 70% of the world's new power investment will take place between now and 2020.
- For international companies, whatever the country, investment strategies should remain neutral in terms of climate change (one ton of abated carbon should be worth the same, at a given time, wherever it takes place). Hence the need for climate change policies that treat all regions the same way, whatever the political mechanisms developed by the UNFCCC.

[14] On a world average, each dollar per ton of carbon raises the full levelised cost of coal-fired electricity by 1%

Hydrocarbons resources

While coal and uranium ore resources are cheap and abundant, hydrocarbons might either become scarcer than they were since 1982, or/and become more expensive that they used to be. Two problems seem to be coming to the fore today, the tightening of non Middle-East oil supply (which could explain the recent oil price surge above 30 $/barrel) and that of the North American natural gas supply.

Oil shocks and lagged price effects

The modern world oil market began just after the end of WWII with two salient features, permanent since that time, the end of the oil autarky of the USA (becoming net importer of oil and petroleum products in 1948) and the rise of the Middle East region with the start of the Saudi exports (posted prices officially switched from the Gulf of Mexico to the Arabo-Persian Gulf in 1950). In addition, these two features appear to be linked from the beginning because of the close correlation between US net imports and Saudi net exports.

Graphs 13[15] and 13bis (logarithms) show the story of oil prices (Arabian Light up to the early 80s, Brent afterwards) expressed in constant 2000 US$ to get rid of the distortions created by the high inflation periods. According to my interpretation, there are two or three different periods, firstly from 1948 to 1969, secondly from 1974 to 1999 (with a political high price 1979-85 parenthesis) and a possible third one starting now.

The first period. From the after war to 1969-73, oil was cheaper and more competitive than the other energies and increased its market share, in particular heavy fuel oil in the power sector at the expense of coal. Price was smoothed by the "Seven Sisters" but its 3% annual decline because of the rise of productivity as well as the normal (same as that of the other industrial sectors) profitability of the oil industry are clear indications that there was no market power abuse and that oil price was set on the marginal barrel, that of the US up to 1959, that of OPEC afterwards. Independent US oil producers, because of their higher costs, were faced with the shrinking of their revenues and the growth of the cheap Middle East imports. They took the Suez' crisis in 1956-57 as an argument to get special protection from the Federal Government. The initial "voluntary imports quota" of 1957 did not worked and President Eisenhower made them "mandatory" in 1959. The US were disconnecting their domestic oil market from that of the rest of the world, leaving to the large foreign producers the responsibility of managing the market, what they did by creating OPEC the following year, in September 1960.

The transition. It started in 1969 when the Santa Barbara oil spill triggered some important US environmental laws (Clean Air Act, Clean Water Act). They slowed down the development of domestic energies (mostly coal) at the very time when the US indigenous oil production was going to peak (1970) before decline (see graph 14[16]). US net imports, which since 1959 were kept at about 20% of US consumption, were relaxed and grew by 25% each annum from 1970 (3.15 Mb/d) to 1973 (6.02 Mb/d), a growth perfectly matched by Saudi net exports. World oil market became tight, as revealed by the successive upwards price revisions in Tehran, Tripoli and Geneva before the October 1973 oil price explosion. The "Club of Rome" was right, oil was unable to fulfil all energy needs, but it was wrong because oil was only scarce in the US 48 lower states but abundant elsewhere.

The second period. The first oil shock revealed that oil had to share the energy market with the other energies. Nobody knew what the right price of oil was except that it had to be low to keep a large enough market share for oil, and not too low not to discourage other energies to the point an oil shock would become inevitable. This trial and error adjustment process gave birth to a large volatility around a trend that, again, declined by about 3% per annum (in constant money) because oil was abundant and able to match the productivity improvements of the other energies. At 18$/b, the average Brent 1999 price was close to the trend value of about 17 $.

NB. During that second period, internal Iranian political problems in 1978 led to the strike of oil workers and a severe fall of Iranian oil exports more or less matched by a similar increase of the other producers. Yet, because of the attitude of the international oil companies (building stocks and, by so doing, pushing the price up) and the signature of Camp David peace agreements, Saudis decided to cut exports by 1 Mb/d, starting April 1, 1979. Oil price "exploded" then, followed by the second price explosion of September 1980 (outbreak of the Iraq-Iran war) and the high prices episode (thanks to increasingly severe production cuts) up to the end of 1985.
The view that oil demand fell during 1979-85 because of the high price episode and rebounded in 1986 because of the low price is not correct because it ignores the importance of the lagged price effects. In reality, this high price episode coincided with the coming on stream of many hew investments launched after the first oil shock. For instance, in the power sector, Utilities decided to build new coal-fired or nuclear plants in order to reduce the

[15] See "Le prix du petrole", Revue de l'Energie, n° 516, May 2000, by Paul Alba and me.
[16] Courtesy of Jean Laherrere and WEC (ETWAN)

dependence on oil. These new plants, ordered after the first oil shock (1974) up to the beginning of the recession and drop of demand of the second oil shock (1980), came on stream between 1980 (1974+6 years lead-time) and 1985 (1979+6) and reduced the oil demand. From 1980 onward, Utilities were squeezed between a flat or declining electricity demand and the growth of their new capacities. They stopped new orders and, from 1986 (1980+6 years lead-time) onwards, no new plant came on stream and oil demand rebounded.

The third period? The recent 2000 oil prices, in excess of 30$/b, are much above the previous trend and could signal the beginning of a third and new period, that of higher prices to compensate for the coming decline of the non Middle East oil production. This is analysed in the following paragraphs.

<u>The non Middle East oil supply today</u>

The first turning point occurred when the supply of the USA began to decline (graph 14), some 35 years after the peaking of discoveries in the mid 30s (see graph 14bis which shows the peaking of oil discoveries). Another turning point seems to be happening today with the peaking of non Middle East oil production (graphic 15[17]), some 35 years after the peaking of the discoveries in the mid 60s (see graphic 15bis which shows the peaking of oil discoveries). Is it true? Does that explain the recent oil prices? And how are the oil and world energy situations going to unfold? The answers depend on a number of factors, especially the amount of new oil reserves (reserve growth of existing fields and new discoveries) to be possibly added in the years to come.

Reserve growth. Initially declared reserves are always conservative (oil companies hate downwards revisions) and sometimes very conservative (the case for onshore US fields because of the combination of stringent SEC[18] rules and early production decisions). That leaves room for re-appraisals and reserve growth. However, for the 1995-2025 period, I only expect a 200 Gb reserve growth because of the following caveats:

- Firstly, because they are located offshore or in harsh conditions, more and more fields are better appraised before declaring their reserves and putting them into production. That reduces the uncertainty and therefore the potential for reserve growth.
- Secondly, in most non-US countries, the maximum allowed production rate will depend on the amount of declared reserves. That creates an incentive to better assess the real potential of the field, leaving less room for re-appraisals and reserve growth.
- Thirdly, revisions mainly occur during the early years of production. Uncertainty becomes smaller after a number of years of production. The giant fields that are now 30 years old and still make the bulk of world production only have a limited remaining potential for reserve growth.
- Fourthly, at constant oil price (because, on the short run, costs and prices are correlated), technology reduces the costs (3% per annum), increases exploration success ratios and shortens production lead-times. However, in most fields, recovery factors face natural limits[19] that cannot be overcome incrementally.

New discoveries. With the exception of the new recent deep/ultra-deep offshore (mostly Gulf of Mexico, Brazil and Gulf of Guinea) and Kashagan super-giant discoveries, each possibly amounting some tens of Gb, recent annual discoveries have been less than 10 Gb and declining. This is why I only expect total new discoveries between 1995 and 2025 of about 200 to 300 Gb.

These two figures for reserve growth and new discoveries between 1995 and 2025 are similar to those of the IEA 1998 World Energy Outlook[20] but much smaller than those of the recently published USGS[21] new study:

- Reserve growth: mean (expected) value of 730 Gb of liquids (76 Gb of oil and NGLs in the US, 612 Gb of oil and 42 Gb of NGLs for the rest of the world),
- New discoveries: mean (expected) value of 939 Gb of liquids (83 Gb of oil and NGLs in the US, 649 Gb of oil and 207 Gb of NGLs for the rest of the world).

[17] Courtesy of Jean Laherrere and WEC (ETWAN). See also http://www.oilcrisis.com and http://dieoff.com/page140.htm

[18] According to the Security Exchange Commission, declared reserves should be developed proved reserves. While there is no agreement on the probabilistic meaning of this definition, an acceptable subjective calibration would be a confidence level of 95% probability to have at least this amount. If one compares that value to the expected (i.e. average) value, the ratio is 1 to 6 or 7, meaning that an initial proven barrel will end up after say 50 years as 6 or 7 produced barrels.

[19] In the North Sea, in absence of previous experience, the initial assessment of the water flooding was on the low side. The good surprise brought by Mother Nature was that the diagenesis of the sand reservoirs brought a much better water drive that expected with secondary recoveries up to 60%. This had nothing to do with technology. Furthermore, once this recovery has been achieved, there is little chance, if any, that the remaining oil can be produced any foreseeable day at present oil prices.

[20] See chapter 7 (pages 83 to 121) and the box 7.3 for more discussion. The opinion of the author of this paper is that, given the large share of "old" giant fields in the present oil supply, for which the process of reserve growth is coming to an end, the overall prospects for reserve growth are small and make the upper figure of the IEA range (3000 Gb of liquids) extremely unlikely.

[21] See http://energy.cr.usgs.gov:8080/energy/worldenergy/weppdf/sumworld.xls

My view is that these latest USGS estimates are questionable:

- Firstly, their non-US future reserve growth (612 Gb) is based on the optimistic and un-supported assumption that the reserve growth outside the USA[22] will be the same as that of the 48 US onshore lower States. These 612 Gb of field growth represent 44% of the already discovered non-US 1359 Gb and are unrealistic since reserves reporting is more accurate outside than in the US. Also, one should not overlook what has been described as "political" reserves, including the 300 Gb that certain OPEC Middle East[23] countries added in the late 1980s (their production quota were partly based on reserves) and that exceed the corrections for under-reporting by the industry prior to expropriation. In addition, today's reserve estimates are already based on the latest technologies[24] such as 3D seismic or horizontal drilling, with no room for large growth.
- Secondly, their expected new discoveries during the next 30 years, 749 Gb for the world, are 3 to 4 times larger than what the trend of recent discoveries (less than 10Gb/year and declining) suggest. Furthermore, while the deep and ultra-deep offshore potential has been put up to 50 Gb, the discontinuous nature of the turbidites reservoirs may result in production levels lower than forecast. Similarly the potentially huge Kashagan discovery comes after a very deceiving exploration campaign in the rest of the Caspian area and cannot, therefore, be extrapolated.
- Thirdly, the earlier than initially planned release of their new numbers also comes as a surprise. It occurred at the very time when Bill Richardson, the US DOE secretary, was calling for an increased OPEC production. Is it a coincidence?

The North American gas supply today

Another serious matter of concern is the natural gas supply of the US, Canada and Mexico. A first warning was delivered in the IEA World Energy Outlook of 1998[25]. A second warning is that of the US Management Mineral Services forecasting that the gas production from the Gulf of Mexico will peak in 2005 and then decline. The evidence of the two last years[26] is indeed that of production plateau and increased LNG (liquefied natural gas) imports up to the capacity of available LNG terminals, and a serious maturing and decline of the largest producing regions hardly compensated by Gulf of Mexico deep offshore and coal-bed methane developments.

USGS 2000 Assessment In Tcf	Cumulative production up to 1/1/96	Remaining identified reserves	Expected (mean) field growth Up to 2025	Expected (mean) new discoveries Up to 2025	Ultimate reserves
United States	**854**	**172**	355	527	1752
Others	**898**	**4621**	3305	4669	13493
World	**1752**	**4793**	3660	5196	15401

Based on the share of identified reserves which is already produced, US is a much more mature area than the rest of the world. US remaining identified reserves only represent 17% of the already discovered natural gas, as compared to the rest of the world where 83% of the identified reserves remain to be produced.

In such a context, how to believe the USGS forecast of a more than 5-fold expected increase of the remaining US identified reserves and a less than 2-fold expected increase for the much less mature rest of the world?
How also explain why the USGS range of uncertainty for the new discoveries is much narrower for the US (393 to 698 Tcf, i.e. a 2-fold gap) than for Canada and Mexico (20 to 354 Tcf, i.e. a 20-fold gap)?

[22] The present USGS study contradicts Masters, who was responsible for the previous studies and rejected significant field growth outside the USA in the following terms*: "we assume that many other countries are, in fact, reporting, effectively, an Identified Reserve (Proved + Probable + Possible Reserves) or some major part thereof. In particular, this is considered to be true for all OPEC countries, the Former Soviet Union (FSU), China, and Mexico. The sum total of these major producers accounts for more than 90 per cent of world oil reserves; therefore, we have some confidence that the world value herein reported for Identified Reserves is a reasonable maximum value for known fields and greatly exceeds reserves developed for production."*

[23] The case of Middle East is different because reserve figures are not supported by exploration work and are of a political nature

[24] Sheik Yamani, for example, claims that the recovery factor in Saudi fields will increase to 30% to 45%, giving a huge increase in reserves. He evidently has not realised that the estimated recovery factor in Ghawar, the world's largest oilfield, was already estimated at 45% fifteen years ago, and that its reserves are put today at 115 Gb to be produced with horizontal wells, based on high quality 3D seismic surveys, with a now 60% recovery factor.

[25] See chapter 8 on gas and pages 131 to 133 dedicated to North America. Given the political sensitivity of this matter for the US and Canada, both members of the IEA, the position which was taken in this book is very prudent.

[26] See « htlp://wwww.cera.com/news/media/ 052400 yergin testify.html » the testimony of Daniel Yergin before the US Congress.

III. SQUARING THE CIRCLE OF FORECASTING

What possible energy demand in 2020?

Technology utopia and folly of man

Let me first have a look at former forecasts. By far the biggest past mistakes come from uncontrolled optimism firstly about economic growth[27], secondly about energy efficiency improvement[28], thirdly about the supply of non-fossil fuels[29]. What are the drivers of such wishful thinking? A blind belief in technology and the ignorance of the nature of man.

Technology utopia. Nobody likes to present a gloomy future and energy forecasters, be them company experts, civil servants or independent consultants provide optimistic forecasts about growth and technological progress even though the past evidence is that economic growth has slowed down and results mostly from the growth of the input factors (including energy) and only to a small and unexplained extent from the growth of the productivity of the factors (technological and organisational changes).

Folly of man. Whatever the market fundamentals and their role to explain much of the past energy story, folly of men has come to destroy the most carefully crafted scenarios. The Iranian revolution, which was ignited by agricultural reforms, not by energy matters, the Iraq-Iran war because of the 1975 Algiers treaty[30], the way Russia undertook its market revolution from 1989 onwards, the dogmatism of green lobbies against nuclear, hydro and coal with no other proposals than ungrounded hopes of energy savings or increased availability of new renewables, the refining expansion of South Korea thanks to government support… come against the natural development of economic forces.

Extrapolating primary energy demand to 2020

The evidence of the past trends is that energy demand is driven by the growth of GDP and the reduction of energy intensity, which both depend on how final prices will evolve between now and 2020. If there is no constraint, either from the market place (oil staying around 20 $/barrel) or from the governments of the industrialized countries, one may then expect that energy demand in the market economies (and the economies in transition if their economic and energy behaviours come close to that of the market economies) will follow the same linear trends as those from 1982 to 1997 onwards, with a GDP elasticity of 0.83.

GDP growth. Many forecasters, the US DOE, the IEA (which uses the forecasts of OECD's Economic Department), and the IIASA[31] (which provided the 1993 WEC' scenarios of "Energy for Tomorrow's Word") bet on an average economic growth between 1997 and 2020 higher than 3% per annum, say 3.1 to 3.5, i.e. a 100 or 120% cumulative growth of the world GDP during this period, and a 80 to 100% energy demand growth if the energy demand trends are to remain (for the market economies) or to become (for the economies in transition) similar to the past ones. Given a 1997 world energy demand[32] of about 9.8 Gtoe (of which 7.38 for the market economies and 2.45 for the economies in transition), the 2020 demand would range between 17.7 and 19.7 Gtoe.

One may wonder whether such GDP growth forecasts are consistent with the past data. It is obviously not the case for the economies in transition. FSU recession will not last forever and the resuming of economic growth has already started. In China, future growth numbers will progressively reflect the reality, i.e. a combination of the need for internal restructuring and the impressive prospects brought by a skilful and hardworking labour.

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[27] If one compares the forecast of 1990 energy demand made by the French Petroleum Association in 1970 and the actual demand, the result is about half less the forecast. Of this huge difference, 80% comes from the lower than expected economic growth and only the remaining 20% from the lower than expected energy intensity despite the coming of two major oil shocks.
[28] Pages 194 to 196 of the IEA World Energy Outlook show the difference between the IEA forecast which simply extrapolates the energy-related services trends and the result of the business as usual scenario prepared by the DG XVII of the European Commission with exogenous technological assumptions.
[29] The new WEC's ETWAN report severely downgrades the forecast made in 1993 in ETW about the penetration of new renewables at the 2020 horizon because a closer look at the constraints faced by these new energies demonstrate that there is no way to achieve a market share larger than a few percents at this horizon.
[30] In 1975, the Shah of Iran forced the Iraqis to sign this treaty (putting the border line of the two countries on the Iraqi side of Chatt El Arab) as a means to stop his support to the Kurd attacks from Iran.
[31] International Institute for Applied System Analysis in Laxenburg, Austria
[32] Primary energy demand with Total conversion conventions (all non fossil power sources are supposed to have a 40% efficiency)

In the market economies, economic growth has been slowing down for the last 40 or 50 years, from 5% in the 60s, 4% in the 70s, hardly more than 3% in the 80s down to about 2.5% in the 90s (see graph 1). Extrapolating this trend would suggest an average economic growth of less than 2% for the next two decades. Some will argue that there is room for more optimistic values because of the ongoing institutional and structural changes that may be associated to the rise of a new Kondratiev cycle. Others will call for more caution because of the aging and greying of the world population or because the increasing scarcity of some natural resources might result in negative feedbacks if economic growth were to be higher than its sustainable level. Whatever the arguments for or against rapid future economic growth, the future will reveal that, in the same way as for the past, the average economic growth is not an input, but the result of the succession of rapid growth episodes creating tensions, in particular energy constraints, which in turn will provoke severe economic slowdown episodes.

What do the most recent official forecasts say?

The 2020 total world energy demand for the A, B1, B and C scenarios developed by IIASA for WEC's 1993 book "Energy for Tomorrow's World" (ETW) was 17.2, 16.0, 13.4 and 11.3 Gtoe respectively. These figures are lower than those resulting from the extrapolation, because of the optimistic to very optimistic assumptions made about future energy efficiency improvements.
The IEA figure for the 1998 WEO is 15 Gtoe demand in 2020 according to their own energy conventions and 15.7 with the conventions I use (the same as those of Total). This figure is lower than the extrapolated figure because of optimistic assumptions about the future energy efficiency in the economies in transition and the impact of the anticipated 2010 price rise (17 to 25 constant $/barrel).
The latest 2000 US/DOE/EIA forecast is also about 15.7 Gtoe in 2020 (60% more than in 1997), comparable to that of the IEA and below the straightforward extrapolation. While it is more neutral about the future efficiency improvements in the FSU, it assumes that the energy intensity of the developing countries, which was constant since 1982, will decrease by 1.0% per annum in the future.

In spite of their apparent consensus, these figures raise two questions:
- If one believes that, for the next two decades, the world GDP will grow at an average rate above 3% per annum without price tensions (with the possible exception of a carbon value equivalent to a few US$ per barrel of oil), the consensus primary energy demand of about 16 Gtoe in 2020 is at least 10% lower than what current trends suggest (18 Gtoe). Are they grounds for such an optimism?
- Even with the more conservative figure of about 16 Gtoe of the consensus, the following analysis suggests that there might be a problem of supply if the price of energy is to remain low. What are the supply perspectives for an oil price remaining close to or lower than 20$/barrel?

What supply for the different primary energies?

In terms of final demand, the 16 Gtoe primary energy consensus figure correspond to about 10 Gtoe, of which:
- 20% for electricity,
- 30% for mobility,
- 50% for stationary combustible fuels.

All fuels can be used for heat raising but electricity has no substitute. Even in its potentially substitutable uses, e.g. domestic heating, electricity demand behaves as if it were a captive use. However, electricity is of little use in mobility because it cannot be stored and embarked (electrical trains depend on fixed infrastructures whereas diesel trains rely on their own on board supply). Petroleum products dominate the mobility market because they are liquid, homogeneous and highly concentrated fuels whereas coal, natural gas and even electricity are not. That means that the convenience of use of a given fuel has a positive economic value, whereas the lack of versatility should be considered as a cost. Hence the importance to consider electricity and mobility as two specific services, all the more so as they represent a sizeable and growing (40% three decades ago, 60% today) share of the world primary energy requirements.

Overall, there are four criteria to screen the different primary energy sources:
- Direct costs, including the cost of back-up for intermittent supply,
- Security of supply, both short and long term,
- Convenience i.e. the versatility for mobility and electricity,
- Environment i.e. the local, regional and global pollutions.

The following table summarizes the main features of each energy in relation with these criteria according to my subjective views. None being either the best, or the worst one, should be discarded.

Primary energy	**Direct costs**	**Security of supply**	**Environment**	**Versatility**
CRWs[33]	+	+++	+++	0
Solid fuels	++++	+++	0	+
Natural gas	+++	+	+	+++
Oil	++	0	+	++++
Large hydro	0	+++	++	++
Other new renewables	++	++	+++	+
Nuclear	++	++++	++++ or ++?	++

<u>CRWs</u>

It is difficult to collect and carry them, especially for the poorest people (least developed countries). Climate or weather conditions may put their short to middle term availability at risk. Indoors use is polluting but global sustainability is not put at risk as long as wood collection for direct use of for charcoal making does not lead to deforestation. Lastly, versatility is poor but could be improved if efficient stoves were used.

Even though their relative share will decline (see graph 16), the total amount of traditional non-commercial fuels supply will increase, mostly in the least developed countries, up to a peak around 2030. According to the 1997 IEA database, CRWs represent 1050 Mtoe (hardly 11% market share), of which about 900 Mtoe in the developing countries, mostly non-commercial, and 150 Mtoe in the developed countries, partly commercial[34] and partly non-commercial. In 2020, one expects their relative contribution to continue to decline slightly between the expected 9% share (IEA forecast of 1.4 Gtoe) and a maximum of 11% share (WEC forecast of 1.7 Gtoe).

<u>Solid fossil fuels (coal and lignite)</u>

They are abundant, well distributed worldwide and generally cheap. However, they are not easy to handle for domestic uses and they tend to be increasingly used for very large boilers (industry and power plants) or steel blast furnaces. Coal and lignite are heavy polluters indoors (as long as smokeless and low sulphur coal is not provided), locally (acid rains, heavy metals, ashes unless burners are equipped with scrubbers), and globally (because of their large carbon content and the rather low efficiency of their burners).

Solid fossil fuels (coal, lignite), of which the recent growth has mostly occurred in the power sector, are expected to grow moderately because of the better competitiveness of natural gas, especially in a context of deregulation, and the threat of possible climate change policies (the uncertainty brought by deregulation is a factor of increased capital cost). Their market share (graph 16), which has been on a very slightly rising trend (market share growing slightly above 25%) after the oil shocks[35] (from 1973 to 1985), has resumed its after-WWII falling trend after the 1986 counter-oil shock. Since that time, their growth in the developed countries is mostly explained by the growing base-load use of coal-fired plants (in North America, Japan and Western Europe with the exception, already mentioned, of the UK because of its peculiar energy circumstances). Developing countries, especially China and India, are the only part of the world where coal-fired capacities have been expanding, yet with the limitation of logistics (storage and transport capacities)..

An extrapolation of the period 1986-1996 suggest that the 2020 market share could be around 18 (more likely in the contest of the need to reduce GHG emissions) to 20% (a value associated with a rebound occurring in North America in spite of their Kyoto commitment if natural gas supply were to become too short and nuclear were to be more limited than it is now). The expected contribution would be around 3.0 Gtoe, a figure much lower than the 25% share of the IEA's World Energy outlook (in the BAU scenario, no account was made for the negative effects of electricity liberalisation and climate change constraints) or that of WEC's "Energy for Tomorrow's World" (24 or 22% for scenarios B1 and B).

[33] "Combustibles Renewable and Wastes". It can be either commercial biomass, mostly in the developed countries, or non-commercial, i.e. non-marketed, combustible renewables and wastes in the developing countries.
[34] of which about 3 Mtoe used in power generation in 1995 to produce 128 TWh (about 5 Mtoe in 2020 to generate 200 TWh)
[35] The initial rise occurred because former coal fired plants, which were switched to heavy fuel oil before 1973 were switched back to coal after the oil price shock. The second rise took place between 1979 and 1986 when the new plants ordered after 1973 came on stream. The stop came in 1986 because no new order took place after 1980 since the electricity demand was first falling, then stagnant or fulfilled by cogeneration and gas turbines.

Natural gas

It is cheap, clean and very efficient when used in new modern boilers and turbines (CCGTs[36]). The past record of security is good for international supply but there have been some examples of major regional disruptions (e.g. in Australia) because of trunk-line or gas-plant break-down. Hence, the growing reliance on a few major exporters and infrastructures may become a risk. In terms of environment, natural gas is a low carbon fuel, but, because of the high temperature in the burners, it may generate acidic nitrogen oxides.

North America (Canada, the US and Mexico). As previously mentioned, the up-to-now growth of the supply was fed by the progressive release of the Canadian gas bubble. However, given the shrinkage of this bubble (with the rapidly falling Canadian R/P ratio), the North American gas supply is not likely to grow much in the future. The days of relative natural gas scarcity might have already started with spot prices close or above 4 $/Mbtu and LNG import facilities already working at capacity.

Other non-US regions Should the price of gas at the burner-tip be attractive enough (a concern for Western Europe because the incoming deregulation could drive the price of natural gas down for a decade or so), natural gas is expected to grow fast in all world regions other than North America. A linear extrapolation of the past evolution of its market share (graph 16) would put it at 4 Gtoe (25% market share). However, given that the natural gas supply in North America, which today represents one third of the world gas market, is not expected to grow (the amount of imports to only compensate for the likely decline is already huge, at least 50 Mtoe of imported natural gas as LNG or by pipeline), our preferred figure is 3.5 Gtoe and 22% market share, a figure similar to that of the IEA and of ETW scenarios (22%), but which could be smaller (20%?) in a context of rather low prices, not attractive enough to attract the large new imports which will be needed.

Large hydro

Large dams are controversial. They bring advantages for navigation, irrigation, flood control and power supply at a competitive cost (as long as the cost of capital remains low). Conversely, they have some major problems such as population displacements, silt deposits which fill the reservoirs and limit their storage and power generation capacities, and destruction of some fragile ecological systems. Most of the favourable sites in developed countries are either already equipped or frozen for environmental reasons. In developing countries there remains a large potential in Latin America, Asia and Africa.

Large hydro market share has not much change since 1950 (graph 16). It represents today a 230 Mtoe output, i.e. 0.6 Gtoe of primary energy and a 6% market share if it is measured, as in ETWAN, with Total's conventions (theoretical 40% efficiency). The linear extrapolation suggests it could grow up to 1 Gtoe (7% share and output of 380 Mtoe) but the constraints on new dams and the lack of favourable sites in developed countries may limit its growth (0.9 Gtoe according to the World Bank) and its market share (6%), figures which are the same as those of the IEA and ETW.

Other modern new renewables

With the exception of biomass direct uses, all other modern renewables are used for power generation. Unless in competitive niches (e.g. favourable geothermal sites in Iceland, Italy and the Pacific rim), they are uneconomic and need to rely on public subsidies, ranging from a minimum of say 3 US cents per kWh up to 10 cents and more. The fastest growing ones are wind and solar but they are intermittent and bear a rapidly rising cost for back-up supply when their share in the electricity supply increases. So, even with the 3 cents subsidy, one cannot expect that their share will exceed 5% of the world power supply (i.e. about 15 % in terms of capacity). They do not create harmful emissions but need large areas of land and may bring local sight or noise nuisances.

New modern renewables, including geothermal, only represent a tiny market share, about 0.1% in 1995. Given their constraints, their growth will depend on the amount of public subsidies. A 5 % share of the power output, i.e. 100 Mtoe of final electricity or 250 Mtoe of primary energy[37] in 2020, would the upper limit of their contribution but would only represent a 1.5 %[38] share of the total primary energy demand. A recent analysis by

[36] Combined cycle gas turbines that may use either natural gas, synthetic gas or gaseified petroleum distillates.

[37] As for hydro, I assume that the theoretical efficiency is 40% for all new modern renewables (solar, wind, geothermal, waves and tide)

[38] According to the IEA energy statistics and forecast, they represent hardly more than 0.1% in 1995 and will reach 0.3% in 2020. Given that most of these renewables are intermittent (annual utilizations of about 2000 hours), their corresponding share in terms of capacity would be three times larger. If wind were to provide this 5% contribution in 2020, the total corresponding capacity would be about 700 GW.

Pierre R. Bauquis[39] comes to conclusions that are similar despite a totally different approach. Using the same conversion conventions, he expects that, by 2050, new modern renewables other than the large hydro will only represent 0.3 Gtoe (i.e. a 1.5% market share at this time). For 2020, the total IEA figure, including wastes used for power, is 0.1 Gtoe (less than 1% market share) a figure much smaller than the 1993 WEC[40] forecast.

Renewables were well described by Chauncey Starr, former founder and chairman of US EPRI[41] "*Unfortunately all the renewables face practical barriers. Hydro is obviously limited and has ecological constraints. Biomass involves energy costs of transportation that generally limits its value to about a 25-mile collection radius around the power plant. The intermittency of solar and wind (diurnal availability about 15-30 per cent in the temperate zone) limits their contribution to intermittent supplement. Adding storage for a continuous base load supply multiplies their capital investment by a rough factor of ten or more, making them impractical for such use. …/… Nuclear power is the only non-carbon electricity that can practically meet the bulk of future global demand*".

Nuclear[42]

Nuclear is the most hotly debated energy. Many countries refuse it. Nevertheless, its economic performance is improving and, after the overrun costs and delays of the first plants, the industry is now able to provide standard designs with levelized costs as low as 3 US cents per kWh in countries like Finland or France. Given the large stocks of uranium and the possibility to use recycled fuel thanks to re-processing, nuclear may be considered as a domestic energy supply with no security of supply problem. In the present designs (unlike that of Chernobyl), the risk of radioactivity release seems very small as demonstrated by the Three Miles Island accident. Furthermore, nuclear plants do not emit wastes in the atmosphere.

While its short-term prospects are bleak, nuclear brings an unique combination of economic, security and no-carbon emission advantages, to be balanced against the public[43] fear of a radioactivity release. Today, new nuclear is not needed because overcapacities, mostly revealed by the "deregulation"[44], exist. In addition, the present uncertainties of the electricity market (nobody knows what the final shape of the industry and the institutional system will be) increase the cost of capital and skew the economic choices in favour of short term solutions such as CCGTs, and in disfavour of capital intensive solutions such as nuclear.

Another constraint that nuclear is facing is its youth. Nuclear industry is still building its track record of safety, reliability (utilization factor), good economics and waste disposal. All these factors, which have played against nuclear up to now, should reverse in the coming years, precisely at the time when new clean electricity base load capacities will be needed. The present 7% market share (graph 16) will first stabilize before a possible decline. Should the decline occur, the market share could then fall to about 5% (4% for the IEA, 6 to 7% for ETW' scenarios). Should nuclear resume its growth, it could reach 8% in 2020, but not much more given the long lead times involved in new nuclear programmes

NB According to Dan Reichter, US Assistant Secretary of Energy (Las Vegas presentation, 25/07/00), US subsidies amounted to 50 G$ (current dollars) for hydro over the century (to be compared to its about 10 % power output share), 25 to 50 G$ for civil nuclear over 50 years (market share of about 20 %) and 13 G$ for new renewables over the last 15 years (output share excluding wastes of 0.5 %). As a matter of comparison, if wind and solar were to reach 5% of the output in 2020, the needed US capacity would be 200 GW at a total subsidies over 100 G$.

Oil, the swing energy

Whereas the other commercial energies have no flexibility because they depend on the availability of long lead time investments (pipelines and terminals for natural gas, coal or nuclear power generation plants, large dams

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[39] « Un point de vue sur les besoins et les approvisionnements en énergie à l'horizon 2050 », Revue de l'Energie, n° 509, septembre 1999

[40] In 1993, ETW (Energy for Tomorrow's World) forecast that new renewables were to make (page 94) either 3-4 or 8-12% of the total energy supply. Further studies, mentioned in the 2000 ETWAN (Energy for Tomorrow's World: Acting Now) come to smaller, more realistic and achievable, figures

[41] Electrical Power Research Institute, Palo Alto, California.

[42] WEC held an European Regional Forum on nuclear in June 1999 in Zurich. A number of papers about the case of Finland, the youth of the nuclear industry, the economics in the new context set by Kyoto, and the issue of democracy for energy choices (see my own contribution: "The Energy Trilemma and Nuclear") are worth reading.

[43] A recent reportage at the French official TV mentioned that the range of death casualties of Chernobyl accident was 15000-50000 (repeating some estimated figures used by "the league of liquidators" or the Ukrainian government who have benefit to worsen the situation) whereas the internationally agreed official estimates come as 31 death casualties among the liquidators and an estimated addition of 1400 thyroid carcinoma, mostly among children or young people. (See Nov; 1995 NEA/OECD report "Chernobyl-Ten Years On-Radiological and Health Impact" and 1999 Official French DSIN report on the same matter)

[44] For instance, if electricity prices were cost-reflective in Japan, as they are in France, they would reveal about 30 GW of peak load overcapacities thanks to a better use of base load and mid load capacities

and massive programmes for new renewables) which are run at capacity, oil can always, thanks to the multi-fired boilers or the idle peaking plants, fulfil the energy needs which are not covered by the other energies. This happened in 1969-73, 1984-85 (coal miners strike in the UK), and every time an unexpected energy need appears. Conversely, each shortage of oil was at the origin of an oil shock and resulted in a drop of oil demand, all other energies remaining more or less at the same level (see graph 17).

Up to 2000, thanks to the idle capacities in a number of OPEC countries and the growth of non-OPEC supply, oil was reasonably cheap with a trend price around 15-20 $/barrel (see graph 13). However, because the oil production outside the Middle East is apparently coming to a plateau (see graph 15), the dependence on the “Big Five” of the Middle-East (Saudi Arabia, Iraq, Iran, Kuwait and the United Arab Emirates) and on a limited number of pipelines, terminals and maritime routes will increase. While the recent oil price hike may be short-lived, it should be a source of concern for all the economic actors because oil is “irreplaceable” for most of its uses (mobility, remote or peak uses, petrochemical feedstock). Its scarcity, either actual or provoked, would lead the world to a major economic recession as it already did in 1973 and 1979-80.

Oil has a high carbon content but it already supports a large tax burden in many countries (not in the USA), often in excess of the cost of its negative externalities, so, with the exception of the USA and some OPEC developing countries, the scope for addressing its environmental impacts is limited.

Oil market share, which was regularly rising up to the first oil shock, is declining ever since with only some episodic upward blips (1986, 1992 and 1997) consistent with its swing role. Sharp declines took place at the time of the oil shocks (1973-75 and 1979-82), followed by the displacement of oil by the new investments up to 1985. The recent period since 1986 is that of a moderate decline thanks to the growth of the other energies.

In the coming years, the likely decline of non-Middle-East liquid hydrocarbons production after its present plateau, will leave more room to the Middle East up to a maximum production level of about 48 Mb/day according to the US/DOE and the IEA[45]. Oil production in 2020 could reach between 4.0 and 4.8 Gtoe, with a most likely value of 4.5 Gtoe, consistent with the extrapolation of the past contribution of non-conventional oil and NGLs. As a matter of comparison, IEA forecast is about 5.3 Gtoe of which nearly 1 Gtoe of “unidentified non-conventional oil”, and WEC forecasts (1993 Energy for Tomorrow’s World) are 4.6, 4.5 and 3.8 Gtoe respectively in 2020 for scenarios A, B1 and B (scenario C should be discarded because of its unlikelihood). In short, the 2020 oil market share could be 30% at best, 28% as the probable value and 25% at worst.

Fitting demand and supply

The following table summaries these analyses and provides the possible market shares of the different primary energies in 2020 for a total primary energy demand of 16 Gtoe. Given that this 16 Gtoe figure is a low estimate (if compared with the extrapolation of current trends when GDP is doubled), these market shares are probably biased towards the high side:

Primary energy	Minimum share (%)	Likely share (%)	Maximum share (%)
CRWs	09	09	11
Solid fossil fuels	18	18	20
Natural gas	20	22	22
Large hydro	06	06	07
Other new renewables	01	01	02
Nuclear	04	06	08
Oil	25	28	30

While electricity generation capabilities are not a problem and oil is abundant enough to satisfy the demand for mobility (at 25 to 30%, oil market share is still much larger than the 18-19% needs for transportation), these market shares are not consistent with the fulfilment of the overall energy demand. The minima add up to 83% (i.e. a shortfall of 17% or 2.7 Gtoe), the likely values to 90% (still leaving a 10% or 1.6 Gtoe shortfall) and even the maxima hardly add up to 100% despite the two hypotheses that nuclear will rebound and that climate change constraints will not harm the development of significant new coal-fired capacities in North America.

[45] See page 104 of the 1998 World Energy Outlook of the IEA

To the question whether the energy supply can meet the totality of energy demand in 2020, the short answer is that it cannot. The consensus scenario is not feasible. In my view, it is obvious that either the prices will not remain at their previous pre-2000 low levels (less than 20$/b on average), or economic growth will be slower than the average 3%+ current consensus, or both forecasts will be wrong.

Is a new oil shock possible?

"An early perception of nascent harms, which is only given to the wise man, will allow to find remedies quickly. But, if failing to notice them, one lets them grow long enough to become visible to anybody, there is no more remedy" Nicholas Machiavel.

As already mentioned at the beginning of this chapter, high growth episodes will progressively raise tensions in the economic and/or energy system. Given the evidence of the past 30 years (during which the major slowdowns were created by actual or created energy scarcities) and the likely tightening of the energy situation for all fossil fuels (coal because of the impact of climate change policies, North American natural gas supply and oil maturity outside the Middle East), I do not think it is possible to have a smooth energy path from now to 2020 except maybe if oil prices were to remain above or around the 30 $/b mark. Will the folly men add the worst to the bad is still an open question but Murphy law tells us *"when something can go wrong, it will"*.

In such a perspective of possible dramatic adjustments of the energy market by price shocks, one should keep in mind what the mechanisms of such price shocks are. Price shocks are both the symptoms of the lack of energy to feed the potential economic growth and the remedy to create new rooms of manoeuvre:

- The argument that energy shocks will be less dramatic or not exist anymore because energy is only a tiny share of the world GDP is wrong. The linear linkage between GDP and energy demand shows that energy is as indispensable for the economic system as blood is for man's life. Furthermore, because the lead times to change the energy infrastructures are long (more than 6 years), the only short-term flexibility is a halt in the economic growth.
- The argument that the world is now better prepared to cope with an energy disruption is wrong. Most of the easy to displace fuel oil consumption (that of the power plants in the 70s and early 80s) is now gone. Captive sectors demand is more difficult to reduce and will require much higher price signals than those of the past shocks. Energy systems of the 70s were like a fat man who could loose weight without too much pain. Today, they look more like a skinny man who can die in case of famine.
- The argument that, thanks to the new *e*-economy, the paradigm of economic development has changed is wrong. The consumers of developed and developing economies continue to desire large houses, large cars and SUVs, more and more appliances and leisure trips abroad, etc. They will not change their minds unless energy costs rise so much that they really cannot use it in the same way anymore.

What could the next oil shock be?

Three digit oil price. Oil price is the signal to slow down or to stop the economic growth in case there is no more extra energy to fuel it. The resilience of most economies against imported inflation and higher interest rates is not good news in that context because it means that a much larger price signal will be needed for the consumers to really feel the pain. The other sad news is the absence of "fat" in the energy system because oil is now mostly used in captive sectors. Examples of the consequences of an energy shortage are shown by the North American natural gas market: when the supply tend to become tight in certain areas. When the rooms of manoeuvre provided by interruptible consumers and all short-term supply mechanisms have been used up, prices shoot up to several tens of $/Mbtu.

North America, driven by the US, is the most price sensitive region. It is the largest consuming region and that where the level of energy fixed costs and taxes is the lowest in the world. This low level works in favour of the consumers as long as the variable costs of energy is low but it works the opposite way in the case of a price hike because the price absorber effect of these low fixed costs and taxes is much smaller than in countries such as Western Europe or Japan. Graphs 18, 19 and 20 show the primary energy demand trends of North America (US and Canada), Western Europe and the developed Asia-Pacific region (Japan, Australia and New Zealand). Even though North America had a much larger share of indigenous oil supply in the seventies than Western Europe and Japan, it is the region where the two oil shocks of 1973 and 1979-80 made the worst impact. In the future, should nothing be done to enhance its security, North American sensitivity to an oil shock is to increase, together with its growing dependence on imported foreign oil.

IV. KEEPING ALL ENERGY OPTIONS OPENED

Many physical (nature of the portfolio of primary energies), economic (direct fixed and variable costs, taxes on behalf of externalities or not) and institutional (competitive market or monopoly, state-owned or private sector) factors affect each national or regional energy "system" and will result in a combination of degrees of freedom and constraints.

Within each particular set of opportunities and constraints, a good energy strategy will ensure that:

- The energy portfolio is cheap, secure and environment friendly,
- The drivers of energy demand are identified and the future demand met,
- There is enough fuel flexibility to adapt to changing circumstances

To achieve these goals, there is an obvious need to keep all energy options open with four practical recommendations:

- Do not put all your eggs in the same basket,
- Adapt energy taxation to the identified externalities,
- Create new rooms of manoeuvre with R&D,
- Increase public awareness.

<u>Not putting all the eggs in the same basket</u>

My views regarding each individual primary energy can be summarized in the following way:

- CRWs will continue to be an important contribution in the least developed countries the more so if it used in efficient stoves (See WEC's *The Challenge of Rural Energy Poverty in Developing Countries"* published in 1999).
- Large hydro can bring important energy and non-energy (irrigation and navigation) benefits. It should not be systematically discouraged. Careful environmental impact studies will help to select the best locations.
- Even though nuclear needs to overcome its youth problems[46], it should neither be captured and condemned by a minority of green activists, nor only supported by a nuclear lobby without any public say. A democratic, transparent and well-informed public debate is needed.
- New modern renewables will be needed in the future either directly to generate electricity for niche uses or indirectly thanks to their passive contribution in better designed buildings using the warming or cooling effect of sun, wind and ground subsurface thermal inertia.
- Coal is a large and cheap energy source in many countries, particularly some developing countries such as China and India. Its clean use may bring an important contribution to electricity generation or to the synthesis of liquid hydrocarbons.
- Natural gas development depends on international infrastructures. The signature of the Energy Charter Treaty will ease their rapid development. Gas to liquids technologies may also provide a means to use some (900 Tcf) stranded, presently uneconomic, gas deposits.
- Oil is a condensed and liquid energy. It is easy to transport and to store, making it an exceptional and unchallenged fuel for transportation, as well as for remote and peak uses. In case of scarcity, the only short term adaptation is a shrinkage of the GDP.

This quick review confirms that no energy source is today systematically either better or worse than the other ones. Every different primary energy brings its own bag of mixed benefits and drawbacks. Nor can one anticipate that, within the planning horizon of the Industry, one source of energy will emerge as "the" solution or will have to be definitely dropped. One therefore needs, for a good energy portfolio, to keep all energy options open and not put all our energy requirements in a too narrow basket. In addition, one should aim at improving their benefits and reducing their drawbacks by a combination of:

- regulation/taxation policies,
- research & development programmes
- information and public awareness

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[46] Refer to the discussions held in Zurich by WEC's European Regional Forum in June 1999 (already mentioned in a previous foot-note).

Adapting energy taxation to identified negative externalities

Energy price is a fundamental signal. It carries information allowing the consumer to substitute energy or to increase its use, at least to a certain extent, at the expense of other economic inputs such as capital and labour. Hence the importance of cost-reflective price signals including both the direct costs (fixed and variable costs of producing, transforming and transporting energy) and the negative externalities (security of supply and environmental constraints) that each energy carries. Another component that plays a role in energy choices is the convenience, i.e. easiness to use, of a given fuel. It works like an implicit positive externality according to which consumers are ready to pay a premium price for convenient fuels, be them electricity for heating (as compared to coal, oil distillates and even natural gas), oil products for transportation and remote or peaking uses, coal against CRWs for cooking, etc.

In addition, price signals will only work their way if the appropriate institutional setting exists. Consumers should have the obligation to pay the price (no subsidies or exceptions) and the right to be "empowered[47]", i.e. the possibility to choose the energy service and fuel they want on a level playing field (no de-jure or de-facto monopolies or oligopolies which either prevent the price to reflect costs or/and limit the choices offered to the consumers).

Security of supply

Solid fuels, natural gas and electricity. Security is not an issue for solid fuels (CRWs, coal and lignite), hydro and nuclear. It could become one for natural gas given the increasing dependence on remote imported gas and the existence of large potentially fragile infrastructures. Yet, for natural gas and electricity, the very existence of a physical grid implies that there is a single supplier at a given time and location to whom the consumer may "buy" his desired level of security, e.g. thanks to premium attached to the cost of the commodity. It will then be up to the supplier to find the best supply-demand portfolio providing the desired security levels at the lowest cost.

Liquid hydrocarbons (oil). Part of oil products are used in the "captive" transportation, petrochemicals and non-energy uses sectors where there is no inter-fuel competition. While transportation prices do not much affect the international competitiveness of a country (that explains why gasoline and diesel taxations vary so much among the different regions), oil feedstock price is an important component of the international competitiveness of petrochemicals and leaves little room for taxation unless it applies to all countries. In the sectors where inter-fuel competition exists either fully (large industrial users and power-plants) or at the margin (residential & commercial) any change in the taxation regime of a given fuel will work as a subsidy in favour of the competing fuels. This maybe of little relevance when this subsidy favours indigenous natural gas and does not hamper the competitiveness of the country but it becomes a key issue if natural gas is imported (because it provides a rent to the foreign suppliers) or/and is heavily used by the industry (because it hampers its international competitiveness).

NB. The case of domestic transportation

On the one hand, it is a captive sector for gasoline and diesel with no inter-fuel competition and hardly any impact on the international competitiveness of a country. On the other hand, transportation involves the largest share of oil consumption in most countries and is essential to the economic activity. Hence the importance to design a taxation system that reflects the negative externality associated with possible supply disruptions. It should be based on two common sense remarks:

- Firstly, the very fact that excise petroleum taxes are small in the countries which were historically self-sufficient and high in the countries which had to rely on crude imports indicates that the greater the dependence on foreign oil, the higher the level of tax to reflect the security risks.
- Secondly, the risk of supply disruption is smaller in an over-supplied market, i.e. in a context of low pre-tax prices, and greater in a tight market, i.e. in a context of high pre-tax prices. Hence the idea that security externalities should amplify the price signals and not mute them.

These two remarks suggest that the best excise tax should be proportional to the pre-tax price at the refinery gate and that the coefficient of proportionality should be the same, say 3 to 4 based on the actual European and Japanese figures, for all importing countries (the price elasticity of this oil demand being small, the size of the imports is generally large and will not be much affected by an oil crisis, at least in the short run).

[47] See : « Energy after the financial crises", ESMAP (World Bank) Energy and Development report, 1999, and my own contribution pages 56-59 « Empowering the End-User: Market Reforms Lessons from the IEA Countries ».

Such a taxation policy has the advantages of amplifying the "natural" price signals and favouring a better producers-consumers inter-action (demand addressed to the foreign producing countries would be increased in case of an over-supplied market because final gasoline or diesel price would be further lowered by the proportional taxation and vice-versa in the case of a tight market).

Should the Us government adopt progressively this taxation, it would find two additional advantages:

- To relax the pressure on oil demand (US alone represent about 25% of the world oil consumption),
- To lower the present US high sensitivity to an oil shock down to that of the other developed countries.

<u>Environmental constraints</u>

In the second part of this paper, I have set four general principles for good climate change policies. In short, the best approach to reflect the perceived climate change threat should combine the advantages of flexibility brought by market mechanisms such as tradable emission permits and those of an identified universal price signal such as a given carbon tax or a cap provided by a penalty in case of non-compliance. Taxation (based on the carbon or carbon-equivalent content) would apply to the captive residential, commercial and transportation sectors, and carbon quota would be imposed to the competitive large industries or power-plants sectors with a marginal penalty equal to the carbon tax in case of non-compliance, once they have used all the possibilities offered by their own international operations (CDM or CDM-like mechanisms[48] in the developing countries, trading and joint-implementation in the Annex 1 countries).

As already mentioned, an order of magnitude of such a tax or penalty could be 20 $/tC, equivalent to 2 $/barrel of oil, increasing over time with a doubling in constant money every 10 years. Coal-fired plants would be first affected, then smaller coal or oil boilers and transportation would only feel the bite in say 40 years from now.

<u>Creating new rooms of manoeuvre by R&D</u>

Given the possible evolutions of the energy supply and the rising constraints in terms of security and environment, a number of R&D programmes need to receive adequate support. The following suggestions are not intended to be an exhaustive list but rather to indicate the wide range of domains where one should seek further significant progress:

- Increasing the role of renewables for their niche markets and the passive use of sun, wind and underground thermal inertia in new housings,
- Enhancing the economics of nuclear fuel plants and the safety of nuclear fuel and waste cycle thanks to improved evolutionary, and possibly new revolutionary, designs,
- Widening and spreading the concept of hybrid cars which combine a smaller and more efficient thermal engine and an electric system (batteries and motor),
- Improving fuel cells and the hydrogen-based designs (choice between large-scale production with local storage and small-scale hydrocarbon conversion devices).
- Understanding and measuring the welfare benefits brought, at a same energy consumption level, by an increased energy efficiency,
- Bringing GTL or CTL (gas or coal to liquids) technologies to a competitive cost in spite of their drawbacks in terms of carbon emissions.
- Etc.

Whatever the funding, private money for programmes aimed at creating a competitive edge or public money for programmes benefiting the whole Society, the best drivers of R&D are and will remain:

- clear signals (provided by the prices and their announced evolution)
- "empowered" consumers (thanks to their capacity to make their own well-informed choices)
- national or international competitive pressure (even for public-funded R&D).

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[48] "Institutional CDM" (see the 6th action proposed in "Energy in Tomorrow's world") could be an attractive scheme for the industry. For instance, an industrial company could take a financial participation in a mutual fund aimed at buying the carbon credits earned by the introduction of market reforms in developing countries (e.g. to introduce an excise tax on gasoline and diesel in China since none exists today) as long as such reforms do contribute to reduce fossil fuel consumption and lower carbon emissions.

Involvement of public in energy choices

Some fundamental truths are worth saying to the general public, national policy-makers and international negotiators:

- There is no magical gimmick to reduce energy, transport or electricity demand,
- There is no past evidence to suggest that A. Lovins could be right tomorrow with the electricity demand flattening or even declining and making coal, large dams and nuclear useless,
- There are choices and compromises to be made, based on the actual evidence of past data and trends, not on ungrounded optimism.

In developed democracies such as ours, one cannot simply say that the public is not well informed or is unable to balance the risks and rewards. Public opinion is of a critical importance and merits a transparent and well-informed debate. For that purpose, electricity and gas deregulation offer the possibility of a bottom-up based process for energy choices (each consumer choosing his supplier, his price formula for the commodity and his required level of security of supply) instead of the former traditional top-down approach where governments were making decisions either directly (in case of state-owned Utilities) or indirectly (privately-owned Utilities with strong public regulations). one) on behalf of the consumers.

Public should know the real costs including those brought by the risks of disruption (how costly is the insurance against such risks?) and environmental constraints (what is the amount of direct subsidies and the cost of back-up because of their intermittent nature that new renewables bear? What external costs are borne by large dams, nuclear, oil, natural gas and solid fuels?). Given that information, some consumers may prefer renewables even though the cost is significantly higher, some others may prefer gas but will also request significant reliability levels that a single gas source will not be able to provide; others will simply refuse nuclear, etc. This bottom-up process will give birth to a natural democratic process of selection combining the individual preferences in terms of cost, security and environment.

When individual choices cannot be made, e.g. for oil products (because all commercial transactions are on a spot basis) or for global climate change concerns (because none is harmed by his own emissions), taxation should reflect their public goods dimension, namely the security of oil supply and the protection of environment. Nobody likes taxes, the more so if the purpose of taxation and the use of the collected funds are not clearly put to the public. Hence again a need for information and education with open debates, independent expert testimonies, and parliamentary discussions before decisions are made.

Conclusion

I have moved backwards to the future, revealing the aggregate drivers of energy demand and today's challenges. Some may regret that I did not addressed a number of important energy questions. In particular, I left aside the problem of the pattern of individual energy consumptions in a country and the interface between energy policies and social policies (how should taxes and penalties be recycled in the economy? how to get the prices right while protecting the poor? how can market reforms be equitable? etc.). I also left aside the question of international equity and the multiplier effect of cooperative actions between developed and developing countries (in a global society, may we imagine to be better off at the expense of the other countries? how to lower political risk and increase foreign direct investments[49]?). Lastly, I left aside the possibility of an energy "soft-landing" with a smooth long-term reconciliation between energy supply and demand (is the present oil price, say around 30 $/b, high enough to slow down the demand, increase the supply and avoid further oil shocks? will this level be sustained against the market belief, demonstrated by the futures, of lower prices in the short-run?)

My only message is that the next 20 years cannot be the extrapolation of the past decades. There is a need to break the vicious circle of the low energy prices pushing the demand ahead while oil, natural gas and the atmosphere are becoming increasingly scarce resources with prices too low to overcome their shrinkage. We have to face the possibility of catastrophic events, worst than the two previous oil shocks. While such catastrophes cannot be taken for granted, their likelihood should prevent us to adopt "laisser-faire" energy strategies. We need to act now and to take steps to avoid the worst. Future will be what we make it, thanks to our ingenuity and our courage.

"God helps those who help themselves"

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[49] See the actions proposed by the World Energy Council in its latest report (« Energy for Tomorrow's World: Acting Now »)

NB Why are US energy trends shifting downwards in 1997, 1998 and possibly 1999?

Given the size of the US energy consumption, nearly a quarter of the world energy consumption and about 30 % of that of the developed and developing market economies, any change in its energy trends will also be reflected in the global trends (see graphs 3, 4, 5 and 18). Hence the importance of understanding what happened to the US energy trends and especially to the stationary fossil fuel final demand (why is it dropping?).

During these three years, GDP growth was about 4% per annum, an exceptional economic performance which does not seem to be matched by the actual energy demand. Past data show that this kind of temporary mismatch already happened and may provide a set of tentative and provisional explanations:

- Firstly, the potential energy demand was beyond the short term capabilities of the energy system. This may be the case for electricity as it was already noticed in the 80s[50].
- Secondly, when the GDP increases so fast, the consumption patterns of individual consumers may lag their actual new purchasing power.
- Thirdly, the coming to a plateau of the US natural gas supply and the corresponding price increases may have contributed to restrict the stationary fossil fuel final demand
- Fourthly, exceptional circumstances might also had an impact, namely the weather conditions with both lower heating degree-days in winter and lower cooling-days in summer[51].
- Lastly, given the significant reported stock changes of coal and gas, one cannot exclude the possibility of statistical discrepancies that might be corrected in the future.

The only explanation that, at the present time, seems not plausible is that of a structural change in the productivity trends. According to Robert Gordon[52], most of the difference between the 1972-95 (1.42%) and 1995-99 productivity trends (2.75%) is a combination of a cyclical effect and a productivity increase in the durable goods sector (which only represent 12% of the US economy). Furthermore, it is difficult to believe that an overall productivity increase would have only reduced the stationary fossil fuel final uses without affecting the electricity demand or even the mobility demand.

List of graphs

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[50] See " Revue de l'Energie", n° 374, May-June 1985 : "US Electricity needs vs. planned capacity additions" by Chauncey Starr and Milton Searl (EPRI).
[51] See "World oil and gas markets : Myth and realities", 2000 AAPG Annual convention, New Orleans, April 18, 2000, by Dennis O'Brien
[52] See the Financial Times, July 26, 2000 "Not much of a new economy"