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ANNEX 1:
Accounting for sustainability in VLEEM

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Introduction

The new challenges related to the climate change, the depletion of fossil fuel resources and the management of nuclear wastes, as well as the development of the technologies necessary to face these challenges and the long reinvestment cycles especially for buildings, power generation and energy intensive manufacturing, require to consider all these issues over a century.

The on-going VLEEM project has been designed to address these challenges, combining two methodological innovations which are imposed by the very long time-frame:

- an innovative approach of the very long term future, particularly suitable for RTD strategies elaboration: the back-casting approach;
- a re-foundation of the energy-environment modelling structures, in order to properly assess very long term modification of social and cultural preferences and technology evolution dynamics in relation to them.

The use of a back-casting approach is strongly connected with the concept of sustainable development or more generally with a concept of a desirable future. The whole task is to find trajectories able to convert the existing system into a desired future system, of course without violating human rights, the principles of democracy and pluralism. The future state should not be mistaken as an utopian state which should be realised anyway whatever the means to achieve the goal would be. The main reason to use a back-casting approach is to think first about the necessary changes and only then about the problems to implement the change. Then comes the question of political acceptance of the concept and methodology of back-casting, which is a pre-requisite to link the results of the VLEEM study to decision making in the R&D field, which is the ultimate objective of the project.

In VLEEM the energy related needs are assessed with a forecasting philosophy, through general but simple causal relations with demography, wealth and life styles. Backcasting is only applied to the whole chain from the primary energy carriers down to the energy services, the later being taken for granted. Only the technology and the organisation of the energy chain (including end-use of energy) are supposed to enter in the field of the debates and decisions about sustainability, not the population growth or the peoples life styles and behaviours. Nevertheless, it is necessary to clarify under which conditions, about overall human future context, the debate on the very long term energy systems sustainability remain meaningful. Which key context elements would make personal and social life “enough” acceptable throughout the world in one century from now, from cultural, social, economical and geopolitical points of view, so that no major social, sanitary, civil and military geopolitical irreversible catastrophes occurs all along the century. Acceptability in the VLEEM context is understood in relation to four simplified socio-cultural functions : providing, in quality and in quantity, enough food, shelter, self accomplishment and paid work to human beings.

The concept of "sustainable development" should not be mistaken to be an ideology which promises heaven on earth once it is realised. It is more a formal approach to judge decisions and tries to leave freedom of choice between various alternatives.
A very general meaning of the term "sustainable development" was presented in the study "Our Common Future" ("Brundland report) issued by the WECD, a commission set in place by the UN General Assembly in 1983. The report defines a sustainable development as

"a development that meets the needs of the present without compromising the ability of future generations to meet their own needs."
The concept of sustainable development is thus a concept of justice, which can only be justified by ethical means.

Criteria and indexes need to be described, which translate the general definition of "sustainable development" into practical terms. What is the amount of CO2 that we are allowed to emit, how much radioactive material can be produced, which part of the land area should be covered by energy conversion and transportation technologies?…

This synthesis intends to provide the main guidelines about how sustainability is understood in VLEEM, and how it is specified in practical terms.

1. Sustainability of energy systems and policy decisions in energy RTD

Pure academic prospective studies, in particular in the very long term, might well be useless, or even dangerous: inevitably, they create a confusion between the a-priori's and ideology of the academic researchers involved, and the meaning attached to the perspectives by those reading the results, who may confuse them with some kind of prediction.

On the contrary, prospective studies firmly linked to the decision process may have a crucial role if they succeed in providing robust information on the conditions (economic, social, political in our case) driving the success of the decision and on its possible impacts (on energy and environment in our case).

In VLEEM, the ultimate objective is to provide such information to the EC/DG-RTD for decisions regarding major RTD programs in the field of energy. These major energy RTD programs involve very long time spans, some of the expected industrial outcomes not likely to be ready before 60 to 70 years from today (fusion for example). The rationale behind these decision is indeed to prepare alternatives to exhaustible fossil fuels likely to supply the energy needs that the development of the European economies will generate, but also likely to fulfill the more fundamental (though loosely defined) objectives of the EC as regard sustainability.

Therefore, there is a need to clarify how policy decisions, in particular in the field of RTD, actually account for sustainability, and which types of problems this raises. This clarification is indeed a pre-condition to make sure that the prospective information delivered by VLEEM will really be useful for the EC/DG-RTD in its decision process.

1.1 Sustainable development may *hurt*

According to Bruntland's report definition, sustainability is primarily a matter of "ethical" sharing of natural resources (in the broad sense) between today's and future generations. But refraining to use exhaustible resources and to modify the environmental conditions beyond what the market would indicate spontaneously suppose policy actions that may go against existing economic interest and individuals preferences (precisely expressed by the market). It may therefore result that targeting sustainability and trying to foster sustainable development would imply hard conflicts of economic and social natures.

In the VLEEM project, we assume that EC decision makers are fully aware of this question, and ready to tackle seriously these potential conflicts in order to make the necessary changes towards sustainability possible. In particular, we take for granted that there is no a-priori limitations on the prices of energy services which would appear necessary to foster sustainability in energy systems in the future, whatever the mechanisms through which these prices are built up, including taxation, whatever the mechanisms through which these prices are made accepted by the population and the economic actors, including radical changes in the overall fiscal structure, and whatever their consequences on the economic structures.

1.2 «Future generations? What about today's generations?»

Today's generation preferences are known. Those of future generations are not.
Scientific evidence of some environmental problems over the very long term can still be questioned, but the negative economic and social short term impacts of some decisions towards sustainability are immediately experienced. In 100 years from now we will all be dead!
How to balance "hard" environmental criteria for the benefit of future generations with "hard" social and economic constraints for today's generation? This is the key question when trying to establish practical sustainability criteria. Here is the huge challenge for policy makers.

The VLEEM back-casting philosophy implies that precise quantitative criteria are set to define what sustainability of energy systems is, and what quantitative environmental conditions should be respected at the target year by the energy system and technologies (likely to result from EC energy RTD programs) to match the sustainability objectives of the EC. In order to fully account for the necessary trade-off between the severity of these environmental objectives and the severity of the economic and social conditions imposed on the population in between to fulfil these objectives, we will adopt a rather pragmatic approach, reflecting the conditions of this trade-off, rather than a pure normative definition of the criteria. Indeed, the ultimate purpose is to provide useful information to feed the debate on energy RTD decisions in regards to sustainability, not to impose a particular normative view of what sustainability is, and what it imposes on the energy scene.

1.3 Role of scenarios in SD discussions

Scenarios are the backbone of prospective studies. Scenarios intend to be consistent pictures of possible futures and stories about how to reach this future.

It is very common to build a "business-as-usual (BAU)" scenario (or "baseline", "reference", "trend", "do-nothing", "conventional wisdom", etc…) and alternative scenarios, the "BAU" being used more or less as a benchmark, if not as a pure forecast.

Most of prospective studies about sustainability also consider such a "BAU" scenario, but mostly to show how bad the situation would be if nothing is done to foster sustainability.
And here comes a problem as regards how such a "BAU" scenario is received by the decision makers, as well as the sustainability scenarios. Decision makers do not like uncertainty, and any "BAU", because it refers to well known evolutions and mechanisms, and because it has a perfume of forecast (if not prediction), is definitely appealing to them. "OK, most likely, things will be like that". Of course, they are aware that the consequences of such an evolution are bad, that definitely "it is not possible", but implicitly they believe that the problems will find their "natural" solutions through future technology development which are unpredictable today.
At the opposite, sustainability scenarios point out what has to be changed, in technology, behaviours, structures, to reach sustainability. Decision makers are therefore uncomfortable in two ways: change means uncertainty, change means risk (political, economic,…). Provoking the changes through decisions is politically risky on the short term, without guarantee that "it will work" on the long term.

Such an attitude, which is very common in public administrations and governments, relies mostly on the belief that "technology will save the world". This of course must be challenged! Nevertheless, to a certain extent, VLEEM is in the same spirit because of its close relation to energy RTD decisions: we are mostly required to assess how precisely energy technology will save the world!
But we still have to investigate at least how the development of entirely new energy systems would affect behaviours and lifestyles, as for example oil did through the dissemination of cars and the road transportation system.

As a consequence, the VLEEM project will not design any "BAU" scenario. In any case it won't make sense on a century time frame (nothing will be "as usual" on such a time frame), and the question we have to resolve is not to imagine any unsustainable possible future, but how, with which technological development, with which circumstances, sustainability is likely to be reached in one century from now (or before). All VLEEM scenarios will be sustainable scenarios.

1.4 Sustainable Development implies tough political decisions

Among the information and messages that will come out from VLEEM scenarios, two refer to very sensitive issues as regard political decisions:

- Irreversibility created by today's decisions
- The more radical the changes, the more time is needed

These issues are very sensitive because they impact the decision in the short term, although the negative or positive impacts will be visible only on the long to very long term. France must take a decision about the development of the EPR nuclear reactor in the coming months, but this decision will affect the nuclear R&D and future development over the next 50-60 years although sustainability criteria for nuclear have not yet been adopted. Benefiting of a trans-Europe high speed freight rail network in 2050 imposes that decisions are made within

the next few years on huge infrastructures like Lyon-Turin, even if such an infrastructure is evaluated not cost effective today.

VLEEM is focussed first on major energy supply technologies likely to result from the main European energy RTD programs. In that respect, sustainability scenarios will have to point out the irreversibility and the time frame involved by each main RTD programs and expected resulting technologies which may impact EC decisions in the short-medium term. Besides, VLEEM will also reveal the context conditions for these technologies to fully contribute to sustainability, how these conditions are compatible with irreversibility created by current decisions in various fields as transport, urbanisation, grids, etc.., and which time frame is involved for the conditions to be fulfilled in due time. We have to make sure that this additional crucial information is actually disseminated to the appropriate decision makers, and that feed-back to DG-RTD is properly organised.

2. Social viability and sustainability of energy systems

From a socio cultural point of view, "sustainability" can be seen as a global quality approach issue, which suggests immediate changes to improve long term viability of three fundamental components : social, economics, environment, by all necessary means. By social we shall understand the Human Rights Declaration principles. By economics we shall see inclusive activities allowing to meet everybodys' needs (VLEEM identified four human functions) practicing a just distribution of labor benefit, a fair access to education, health care, resources, trade and equilibrated economic monetary exchanges.

As a matter of fact, the concept "development" , as applied exclusively to economics and measured exclusively by the GDP, cannot pretend to cover the whole social and economic dimensions of sustainability[1]. This concept has dominated the second half of the last century in western industrial countries. Every field of human activity was represented and analysed through this filter. But it mainly expresses, justifies and deserves an unipolar vision of the development, aiming to organise the time, the education, the labor, the space, the resources, the imagination, the cultural practices, the artisitic spiritual creativity, the leisure all human existence, and leading practically to reinforce a wealth concentration model. On the very long term, such a "development" can hardly be seen as sustainable on the whole planet.

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[1] Cf. Wolfgang SACHS & Gustavo ESTEVA, *Des ruines du développement*, Ecosciété, Québec, 1996. Also in François PARTANT works : lalignedhorizon@wanadoo.fr et www.après-developpement.org

see also : E.GOLDSMITH, *LeDéfi du XXIème siècle*, Edition du Rocher, 1994, p.330. Exist in English too.

Gilbert RIST, *Développement, la fin d'une croyance occidentale*. Presses de Sciences Po, Paris, novembre 2001.

Review « The ecologist », special edition « To de construct develpoment, to remakr the world », winter 2001..

Cf. Report on Colloque « Défaire le Développement, refaire le monde » (To de construct development and to remake the world), in UNESCO, Paris, february-march 2002. Disponible at ENERDATA (in French)..

To support these considerations, lets' quote M.GOLDSMITH *"It is because vernacular society has adapted his way of life to his environment that it became durable, and it is because industrial society by the contrary forces his environment to adapt to his way of life that it can not hope to survive"*.

Indian Economics' Nobel Price, Mr. A. SEN proposes a broader definition and of human welfare[2], much more appropriate to grasp the "development" in sustainability studies : *a quality of life resulting of improving high standard of quantitative cultural socio economic well being*. His vision is now adopted by the United Nation Program for Development (PNUD). This vision incorporates dimensions pertaining to demography, life-styles and social link, that we will develop hereafter.

2.1 Demography, migrations and sustainability

The fundamental theoretical assumption behind the VLEEM representation is that the economic development proceeds, on the very long term, mostly from the demography and the "human factor".

In the one side, we consider the "labour force[3]" and "information" as the only production factors over the very long range. Wealth is produced thanks to the people at work and their information level. People at work is determined by the volume and age structure of the population. Information level is a direct consequence of how far the people at work have beneficiated from the education system.
In the other side, possibilities for accumulation and conversion of "informed labour" in capital building, is a direct consequence of how wealth is distributed, and in particular what share benefits to categories of people which are not productive any more and which are just consumers (mostly retired people): again the age structure of the population appears as a main determinant.[4]

Beyond its key role in economic development, and then in sustainability, demography raises also questions as regard social aspects of sustainability: inter-generations coexistence, multi-racial, multi-culture coexistence, etc…

How demography and migration impact energy systems in the very long term, according to VLEEM

As previously said, "labour force[5]" and "information" as the only production factors of wealth and affluence in the VLEEM representation. Labour force is expressed and measured as the

[2] **Welfare** *n.*, good fortune, happiness, health and prosperity (of person or community, etc); maintenance of person in such condition, money given for this purpose. In **The Oxford Dictionary.**
[3] In VLEEM, information is a key concept, both to capture the development of scientific knowledge and related technologies, and their impact on labor productivity; it is measured through the access to basic primary, secondary and tertiary education.
[4] CEPII, « INGENUE » model
[5] In VLEEM, information is a key concept, both to capture the development of scientific knowledge and related technologies, and their impact on labor productivity; it is measured through the access to basic primary, secondary and tertiary education.

product of three components: active population (i.e. population likely and willing to work), share of the active population actually at work, time budget for paid work (i.e. annual time spent per person at work for working for money). Information is determined by the former basic education of people at work.

Needs of energy services are determined by two basic influences related to demography:
- a direct influence: the more people, the more needs
- an indirect influence: the more affluence, the more energy services per capita.

Other, more indirect influences, are tentatively captured in the macro-economic assumptions, although not formalised in VLEEM; they are
- the influence of the age structure of the population on the capital formation
- the actual share of active population actually at work

Questions about demography and migrations over the very long term

According to E. Todd[6] , there is an almost irreversible movement worldwide for women to continue their constant progression towards equal access to education, wages and labour positions; at the same time, fertility rate will go down in most prolific regions, creating the so-called "demographic transition".
Recent observations show that fertility might also re-increase in regions where the demographic transition is completed, such as Northern and Western Europe, where it is actually very low. Welfare is directly connected with this possibility, as in order to insure pensions for aging cohorts, financial resources are increased to convince women to procreate. This phenomenon is already observed in Scandinavian countries.
The question is therefore whether very long term stability of the world population is a pre-condition for sustainability, or if fluctuations in fertility rates and population over the very long range may are compatible with sustainability, although creating inevitable turbulences within all world regions, and migrations among world regions.

As a consequence of the demographic transition, a growing density of aging cohorts are to be expected in all regions, which put an increasing burden on the economy, and which may result in strong call for young workers from other regions where the demographic transition is not so well advanced. Today, western industrial aging societies are looking directly for young migrant workers from Africa, Middle East, Far East, Central and South America. These workers are more and more qualified (better informed) and more and more attracted by high salaries in industrial societies. This tendency also seems quite ineluctable. To a certain extent, this phenomena slows down the economic development in the regions from where these workers originate (because it results in a lack of "human capital" in these regions). But, at the contrary, it might also accelerate their economic development if these workers return funds or/and business opportunities in their origin regions.
The question is whether the migrations of workers and population among regions are likely to increase the gap between the riches and the poors, or on the contrary to contribute to some economic convergence through a more rapid transfer of knowledge and funds.

As shown above, some migration is welcome by Western industrialized countries, but some is not. The European policy debate about the "Fortress Europe", the more openly affirmed racial policies of some European political parties, the question of the clandestine immigration, etc..

[6] E. Todd, « Après l'Empire », 2002

show that the migration movement can go much beyond what is currently wished, and raises social problems which cannot be balanced any more by economic benefits.
The question is whether there is some threshold beyond which either the social consensus does not exist any more, creating social unrest retroacting on the economic development, or apharteid-like policies are adopted, creating deep turbulences in international relations and commerce.

A complex issue, usually left aside in energy prospective studies

Surprisingly, most prospective studies in the energy field point out the importance of the demographic factor, but do not account for it practically in the quantitative evaluations: GDP is supposed to account for everything, including the demographic influence.
The reason for that, as pointed out by IIASA[7], is the complexity of the demographic issue, and the extreme difficulty to formalise accurately the relations both sides between the demography and the economic development.
This was confirmed during the seminar on "human development and sustainability" organised by the VLEEM project[8]. In particular, most international prospective studies use the last UN population forecasts, which assumes global and regional equilibria around 2050, where the world population would stabilise around 8 billions people and the fertility rates will stabilise around 2.1 children/woman, independently on the economic development expectations.
This obviously is one (optimistic) scenario, but certainly not the only one that should be considered. It does not say anything about its macro-economic consequences and on where (in which world regions) the world population would actually live, what would be the consequences on the number and structure of the households, etc…

We are aware of the complexity of the demographic issue. But we are also aware that inconsistencies between demographic and macro-economic projections over one century would lead to world pictures without any meaning, in which the evaluation of the needs of energy services would be also meaningless, the description of the energy system supplying these needs in a sustainable way completely wrong (just impossible!), and the messages to decision makers totally misleading.

Therefore, we will propose world pictures for the end of the century in which we will make explicit how the demographic projections are established and how we consider they interact with the macro-economic projections. We will propose to limit our basic assumptions (on fertility, mortality and migrations) within boundaries in relation to considerations with economic and social dimensions of sustainability. We are not willing to propose any criteria for these dimensions, but we will work out indicators enabling the reader of the results to judge how sustainable (from economic and social viewpoints) the world in 2050, 2100 would be.

Suggestions for scenario storylines

Lets' examine the two fundamental assumptions related to demographic development.

[7] private communication with A. Grübler
[8] Paris, ADEME, 30 April 2003 ; see www.VLEEM.org

The first assumption is that of an "explosive" increasing of the population, along with T.R. Malthus statement *"All living species tend to densify their population beyond the limits of what natural alimentary resources allow them"*. This assumption is still a background reference of thinkers and decision makers up today. Most experts affirm that to nourish 9 billions people by 2 050 and 10 up to 18 billions on 2100 (higher UN population' projections) is not a technical problem any more. Although there is no evidence that human population would increase so sharply , even if some very populated regions of the world still experience high fertility rates, this event cannot be rejected since consistent with Malthus prediction. This might be more a question of political willingness, of economic and technical means, of cultural habits, etc... MALTHUS prevision can be true, if nothing is done to prevent such possibility.

The second assumption is that demographic transition towards low fertility rate is unavoidable, along with E. Todd position.. Progress in alphabetization and primary school attendance will at the same time contribute to the emancipation of women (in particular as regard pregnancy) and to the reinforcement of individualism and democracy (less and less possible to "force" , culturally or socially, women to have many children).Whatever the region of the world, outside migrations, the population will peak up somewhere between now and 2050, and decrease afterwards (down to which level?).

Based on these two fundamental assumptions, three "sustainable" storylines scenario can be proposed.

1. High demography in 2100 with near 12 billion people, corresponding to a very slow demographic transition process in developing countries. Countries where religious and traditional cultural determinism remain very strong and where natalist policies are encouraged as birth control forbidden. This particular political context will might slow down meaningfully demographic transition, as it depends on mentalities' change.

2. Middle storyline with a stabilization of the world population around 8 billion people (UN projection for 2050), which means that the demographic transition will be completed in most part of the world by 2050, and that government succeed in convincing educated women to get two to three children in their life. In particular, OCDE societies maintain or rather slowly increase womens' fertility as it is actually de case in Scandinavian countries. Such an evolution might also result from a rising awareness about the need of paying pensions for elders in those societies.

3. Low storyline with little growth, same or less population than today. The demographic transition has been completed by 2050, with a peak population around 8 billions at this time. But afterwards, the combined effect of the inefficiency of natalist policies do not allow the fertility rate to rise again significantly (it remains below 1.8 in average).

A "trans storylines" assumed phenomenon is the aspiration by women to access to constant higher education and labor, that will result in higher feminine professionalism accompanied by a lower fertility rate. Among the various specific sociopolitical and cultural possible situations, Japans is a good example of possible consequences of this phenomenon, where todays' top feminine executives get difficult to live a family life and a maternal experience.
This could result in the fact that increased feminine professionalism might also contribute significantly to the development of unipersonal households.

2.2 Time-budgets, gender inequality , cultural diversity and sustainability

As seen above, in the one side, economic development strongly relates, in VLEEM representation, to labour force availability, time allocated to paid work and people education; in the other side, demographic development is highly related to the maturity of the demographic transition in developing countries, which is mainly a matter of women liberalization through alphabetisation and primary education. The role of women in the social and economic dimensions of the development thus appear crucial in the very long term, through labour force and information level.
Migrations, another key issue as regard social and economic components of sustainability, involve the question of the cultural diversity. This question also affect the future development of international trade and financial flows, i.e. the ability for world regions to build their capital stock and to find clients for their products.

How time-budgets, gender inequality and cultural diversity impact energy systems in the VLT, according to VLEEM

The "human capital" as expressed and measured in VLEEM, involves both genders. Access of young girls to primary education will determine the information level of the economy in the future (and the average labour productivity), for almost 50 years. Access of women to paid labour determine the boundary of the active population and of the labour force. Combination of both determines the potential economic growth of the region over the very long term, and therefore the individual affluence. At the same time, the more educated the women, the less children they have, the less population for the distant future. Therefore, population volume and structure, individual affluence and households number and structure to be reach in 2050 and 2100, i.e. the main determinants of the needs for energy services at that time, appear to be strongly connected to gender equity in VLEEM.

In VLEEM, we assume that time budget structure of individuals and households are fundamentally driven by three major influences[9]:

- Individual willingness to replace time by goods and equipment for domestic functions (mainly food and feeding) whenever possible,
- Individual willingness to replace working time by leisure time (when leisure time value, less related leisure goods and services prices, exceeds working time earnings),
- Social willingness to increase the time allocated to education for further generations in order to improve the information level of the society.

Sustainability suggest that a trade-off is ensured in time budget structure evolutions, between individual and social aspirations in the one side, macro-economic constraints related to the growth of wealth in the other side. As suggested above, this trade-off is strongly determinated by the gender equity reached in the society.
By construction, the needs of energy services in 2050, 2100, are also determinated rather strongly by time budget structures evolution in VLEEM, through individual affluence and information.

VLEEM structure is rather neutral as regard the cultural background, which does not mean that cultural diversity is not considered. In fact, the cultural diversity is captured through regional parameters related to time budget structures, gender specificities in education and

[9] see V. Bagard ; La dynamique du temps de loisir ; research paper, June 2003

access to paid work, fertility rates, elasticities of the needs of energy services to affluence or to time budgets, etc…Of course, the projections of the needs of energy services are strongly related to these parameters! The main issue in VLEEM is therefore to decide how to make regional parameters consistent in a sustainability perspective. Should we consider that globalisation is acting towards some kind of cultural uniformity under the leadership of today's more advanced regions (in the economic sense), which means a convergence of regional parameters over the very long term. Or, at the contrary, should we say that the conservation of the cultural diversity (and related long lasting differences in parameters according to different cultural models) is a condition for very long term sustainability (as in nature)?

Questions on cultural models and their interactions

Persistence, resistance or willingness to adopt changes in way of life, cultural values and mentalities may deepen or reduce social and economic regional discrepancies across the world. Historical empires such the Roman or Chinese in the old times, British, French, Russian, American more recently and nowadays, contribute to make credible the idea that empires can impose longlasting cultural and linguistic convergence around the World, or at least on a regional basis.

World civilizations and cultural models are always driven by a moving permanent dialectics between expansionism of empires and alternative local vernacular resistance. In that respect, the XXI century can be seen as hesitating between two main directions, none of which being incompatible with sustainability:

- Unipolar or bipolar world, through durable domination of the United States empire, with possible emergence of another hyper power within the century (P.R. China?);
- Multipolar world, multimodern societies, pluricultural world, constituted throught the strengthening of regional blocks powers as the European Union, Peoples' Republic of China, ASEAN countries, Brasil Mercosur sudamerican countries, Egypt Middle-East Arabic Muslim countries, or other emerging regional blocs,

USA shows today all the characteristics of a classic empire[10]: the preservation of the US citizen well-being imposes that huge economic and monetary transfers are organized and secured from the rest of the world to the US; the trade balance deficit is the appropriate measurement of this transfer. US culture is expanding worldwide through elites and television, with increasing shares of the population of the world regions adopting US life-styles standards. As a matter of fact, this will have a tremendous influence on the development of the various existing world cultural models and their interactions.

In the meantime, regional blocks of power such the European Union today, probably ASEAN and MERCOSUR tomorrow, China, India, emerge and strengthen. These are strongly based on a common socio political and cultural reference, a free circulation of people, goods and services through an homogeneous market, a monetary union, communication paths. Inevitably the stronger they will be, the more they are likely to balance the US influence, which may

[10] On this matter:

- GALBRAITH, James K., *The unbereable cost of empire.* The american Prospect Magazine, november 2002.
- MEYER, Lorenzo, *The power of one.* Reforma, Mexico, August 5th 1999.
- MITTAL, Amuradha, *The fire on open markets - Strategy of an Empire.* Backgrouder newsletter, Food First, summer 2003.
- MONBIOT, George, *The logic of the empire.* The Guardian, London, August 6th 2002.

result either on the emergence of a bipolar world or on much more diversified multipolar world, with much more diversified life styles.
Also, new ideologies erupt from the social and cultural difficulties originating from the so-called Western style development, which give much more importance to spiritual, sharing and collective values as opposed to consumption, money oriented and individualist dominating ones. Of course such ideologies could lead to very different life-styles as compared to industrialized countries, although among people living in these linguistic and cultural environment, a part still "converge" in material aspirations. Still a more or less important class of people will adopt and have the means to purchase the goods and services proposed by "occidental" technology and fashion.

How the development and interactions of these cultural models is likely to affect our representation of life-styles and aspirations in VLEEM? As a matter of fact, this representation is strongly influenced by the Western European cultural model, in particular when assuming that development goes along less and less work time and increasing self-accomplishment time. This observed tendency in Europe already conflicts with the United States' pension system through the required profitability of shares on the European stock markets. Competition with the developing world put also a high burden on western salaries which is likely to reinforce that already put by the stock markets.
Is this European model compatible with a strengthening of the US cultural model or the emergence of the Chinese one? More generally, to which extent the VLEEM representation of life-styles and aspirations, though strongly inspired by Western Europe of the XX century, is more fundamentally representative of all human being aspirations over the world, and then a necessary component of all modernities?

How these issues are addressed in energy prospective studies: SRES scenarios, SHELL scenarios

These cultural issues are most often left aside in energy prospective studies, except, indirectly in the SRES scenarios, and more directly in SHELL's scenarios.

In SRES scenarios, cultural issues and human socio political acceptance is not taken into consideration. Indeed, the driving forces considered in these scenarios are: demography, economic development (GNP per capita) and technology. They exclude "outlying surprise" or "disaster".

Main Shell concern in scenarios are

- "broad patterns underlying today's' system which are likely to persist,
- forces which influence energy patterns but are unlikely to be fundamental in shaping long term change,
- three likely decisive factors : resources, technology and social priorities."[11]

No doubt that taking into account public opinion and personal priorities, Shell is improving its scenarios .Obviously, citizens demand on renewable energy might impact governmental technological choices and budgets. As well as rejecting polluting energies and radioactivity. "Energy choices are ultimately social choices" concludes wisely the social chapter.

[11] « Energy needs, choises and possibilities ». Shell scenarios to 2 050. Shell International 2001.

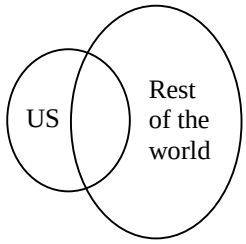
Shells' scenario follows for the long term also a bi polar approach. In the one side, "**Dynamics us usual"** or jet set business class universally and comfortable installed in his privileges among a more or less chaotic world made of extreme cultural social and economical gaps. The level of control and repression of collective protest or insurgency is sophisticated and adapted enough to maintain this model for a long period. It reminds of Japans' *yakusa* controlled neighborhoods and trade unions, where any dissident or rebel rare person is rapidly identified and isolated. It's a "big brother" model extensive to the all world with the arrival of empires' troops and war machinery.

The alternative Shell scenario is "**the Spirit of the coming age**" or cultural multimodern societies one. Which joins the mulipolar vision of coming and changing times. We see already seeds of new kind of social political and cultural ways of production, consumption and socio political organization.

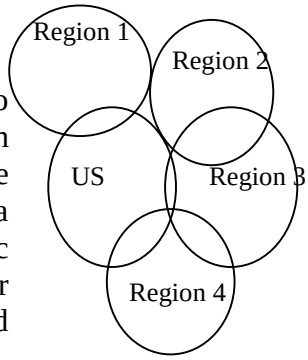
Suggestions for scenario storylines

Schematically, three situations can be envisaged for scenario storylines

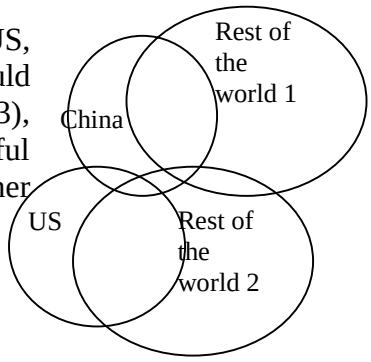
1. Unipolar hegemony, with strong penetration of USA leaded goods, services and fashion. Financial desequilibirum problems can be solved partly through military direct or indirect political control and predatory practices as regard natural resources, in particular energy. A reaction to this leadership might take the form of regional resistance based on cultural and religious traditions. This situation might be rather consistent with the high demographic perspective(storyline 1).



2. Multipolar equilibrated regional emerging powers, leading to medium penetration of this model. Regional blocs based on regional markets' mutual facilities of access will provide relative autonomous regional wellfare, i.e. European union, China ASEAN countries, Brasil Mercosur, Egypt Middle-East Arabic countries, South Africa with Central African Bantu countries or others. This situation could be consistent with the stabilized demographic hypothesis (storyline 2).



3. China emerges as a unique alternative hyper-power to the US, leading to a new bipolarization of the world. This situation could be consistent with the low demographic hypothesis (soryline 3), since the fast declining population in the two most powerful regions would create a strong migration call from other peripherical zones, reinforcing the power of the leading poles.



In all cases, there is more or less diffusion of the USA cultural pattern and life styles, but the process of diffusion is progressive. Probably purchasing power will be determinant to fix the speed of diffusion. The highest speed of diffusion correspond to situation 1, where there is a large willingness to copy and adopt "occidental" USA cultural patterns. The lowest speed of diffusion will be found in situation 3, where there is a strong alternative to challenge the USA leaded "occidental" dominating model : PR China, after almost 30 years of autarchy, ostracism in complete resistance, and after having experienced for a while "occidental" patterns and technologies, then develops and imposes on a large scale an original "model" better fitting with China (and then more generally whole Asia) population density realities.

2.3 How to cope with welfare, poverty and social link?

GDP per capita is usually confused with welfare, and differences in GDP per capita are used to measure poverty.
But, along with A. SEN definition and of human welfare, we will adopt a broader view of these issues, with more appropriate measuring tools.

How welfare, poverty and the social link impact energy systems in the VLT, according to VLEEM

In VLEEM, needs of energy services are directly linked to the production of wealth and the average individual affluence (close to GDP per capita). But they are also determined by information, i.e. access to primary education, and social and economic specificities attached to the various cohorts (in particular domestic and transport equipment, time-budgets). In this respect, they are related to welfare in the broad sense given by A. SEN .
The social link plays indirectly a role, through the structure of the population and households among the cohorts, and through the share of the active population actually at work.

Questions on the measurement of welfare and social inequity

There is already a quite comprehensive tool to measure welfare and inequity, reported in the annual report of UN PNUD on "Human development", the "HDI".

> *"The Human Development Indicator (HDI) measures the average level reached by a given country according to three essential criteria of human development: longevity, access to knowledge and life level. Those three aspects are respectively based on the life hope, the level of instruction (adults alphabetization ratio combined with access to primary, secondary and superior schooling ratios) and income per inhabitant, corrected and expressed in parity of purchasing power (PPP)".*[12]

[12] Translated from French, in ***Rapport Mondial sur le Développement Humain*** 2001 (p.14) , Programme des Nations Unies pour le Développement., Génève.

Linking welfare and sustainability throughout HDI figures then can respond to VLEEM need of an operational concept integrating social and environmental concern, as much as cultural, political and economical one.

HDI allows to define ranking. Comparing HDI levels give insights about the link between a certain social cultural and political option and the human benefit. This rises the question of the possible consequences of a strong persistent HDI gap on the socio-economic conditions for sustainability. Two aspects should be considered, internal and external.

1. Internal gap within each world region, considered relatively homogenous from linguisitic and cultural viewpoints: the higher the wealth, the smaller the HDI gap within the region, the more quiet the social situation.
2. External gap among world regions: the smaller the gap in HDI among world regions, the more quiet the international relationships, the more fluent the economic and financial flows among regions.

The last century shows that there is not an immediate link between social inequality and social instability. But there is a growing evidence that public mental and physical health degradation, violence against oneself (drugs consumption, suicide, risk behaviors) as well as against others (bombing, terrorist suicides, vandalism) are increasing steadily. In principle, democratic systems are able to absorb peacefully periodical social turmoil. But violence may lead democratic systems to protect themselves increasingly through reducing and suppressing more and more civil and human rights, paving the way for totalitarian like *regimes*.

The only limit that we have to consider as regard the evolution of relative levels of HDI, for sustainability purposes, is that the existing gaps across the world will not enlarge.

How welfare and social gap are addressed in energy prospective studies

In practically all energy prospective studies, welfare and poverty are confused with GDP per capita, and the social link is just absent.

Suggestions for scenario storylines

Obviously, there are strong interactions between scenario storylines for cultural diversity and for welfare and social link.

The unipolar scenarios, which combines the predominance of the US cultural model and its world dissemination through the elites, would probably result in an increasing concentration of wealth and an increasing gap between the elites and the rest of the population as regard welfare, resulting in a weakening social link.

The multimodernity scenario necessary implies a reinforcement of the social link around regional cultural values, which supposes a much more balanced welfare distribution within the regions.

3. Sustainability of energy systems: which criteria?

The social and economic dimensions of sustainability can hardly be defined with precise quantitative criteria. As tentatively explained above, more questions than answers still persists on the various aspects of these questions, where ideology is always involved. Different possible pictures of the world can be elaborated for 2050 and 2100 through consistent scenarios; the overall consistency of these scenario can be assessed more or less scientifically and one has to admit that a possible scenario is a sustainable one over the time period considered. Appropriate indicators will also be performed to allow anyone to judge if one scenario looks more sustainable than another, but this will remain for ever a question of personal judgment.

Things are different with the environmental dimension of sustainability, in particular when it refers to a sectoral issue like energy. Here we have to decide what is acceptable on the very long term, and what is not, from a pure ethic viewpoint. In other words, we have to settle pre-defined quantitative criteria measuring precisely the red line not to be over-passed.
As said earlier, to be effective for decision making, these criteria should in any case result from a negotiation procedure where all stakeholders must be involved to actually properly balanced the short term drawbacks on economy and society of the decision with the environmental benefits for the future generations to come.

These are Herman Daly five principles of sustainability relevant for environmental consideration (from TIPPETT, p. 16) :

1. Waste emissions should not exceed the regeneration rate.
2. Human scale (throughput) should be limited to a level, which is within carrying capacities.
3. Technological progress for sustainable development should be efficiency increasing rather than throughput increasing.
4. Waste emissions should not exceed the renewable assimilative capacity of environment.
5. Non-renewable resources should be exploited but at a rate equal to the creation of renewable substitutes.

3.1 The climate change issue

The climate change debate is strongly coupled to the debate about sustainable development. It might turn out that the anthropic emissions of green houses gases will become the most important environmental sustainability issue.

Why it is really an issue

Climate change is not, by itself, something new on earth. Geological observations show tremendous changes over the history of earth. What is new however today is that we are out of any geologically recorded variation (speed) boundaries for CO2 concentration of the atmosphere and average temperature on earth. Linkage with the anthropic emissions of green house gases, in particular CO2 released by fossil fuels consumption, has been scientifically established, but the consequences over the long and very long term are still a matter of tough

discussions among scientists, and between scientists and policy makers. In any case, the fourth H. Daly's principle is being violated.

Depending on the scenarios established by the meteorologists, some people would appreciate the consequences of the climate change, other not at all. This makes the international negotiation on voluntary reduction of green house gas emissions even more difficult.

Nevertheless, the fundamental equity dimension behind the sustainability principle obliges to consider that a red line actually exist, beyond which human, ecologic, economic and social disasters are likely to happen in various parts of the world, which could be and must be avoided.

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No absolute criteria, but negociated ones: the SRES scenarios

The international community, both scientists and decision makers, is now fully aware of the problem and tries to find an appropriate trade-off between the necessity to limit the green house gases emissions below the red line, and the economic and social costs involved in the various parts of the world; between those who consider that the red line should adapt to the short-medium term economic constraints, and those who consider that the economic and social effort should adapt to the red line.

For example, the SRES scenarios adopted by the IPCC to figure out sustainable futures as regard the climate change thus consider different levels of constraints on world emissions of green house gases: the goal is to provide appropriate information for the democratic debate and the international negociations, not to say "the truth" on this issue. What appears the most important for the IPCC is the ability to evaluate all the consequences of these emissions (physical, economic, …) at the different emission thresholds, and how these thresholds are obtained, rather than trying to "discover" and "propose" the "best" threshold.

Which criteria for VLEEM ?

So, it is by no means obvious which emission level should be reached at which point in time. Three major uncertainties dominate the discussion: how much CO2 will at the end stay in the atmosphere, how will the climate really change by the increased greenhouse effect and how will the socio-economic system be affected by these changes. As said above IPCC tries to give answers to these questions, but did not formulate precise goals for emission levels yet. In some countries national bodies like special commission to the Parliaments or parties formulated precise goals. In OECD countries reduction levels between (50-80) % related to the emission levels of 1990 are mentioned.

In VLEEM, the debate will be attacked from the future, consistently with the back-casting approach . The first answer is, a CO2-concentration stabilisation has to be reached at some point, if the climate system should not become completely unstable. This requires on the other hand, that at some point in the future (next 100-200 years) the emission level from fossil fuel combustion has to become roughly zero. This sets the goal: only zero emission technologies from some point in time on. This is still a too soft statement to develop precise pictures of the future. The final goal will certainly be set by a negotiation process, it will strongly depend on the overall political situation, the geographical distribution of impacts and the economic

situation and especially the economic disparities and last but not least on the scientific evidence to couple certain impacts to greenhouse gas emissions. This implies that the final emission goals have to be set during the analysis phase in a consistent manner. If it becomes evident that certain weather phenomena (especially extremes, like the summer 2003, or the floods in central Europe in 2002) are strongly coupled to men made greenhouse gas emissions, then more stringent emission goals seem feasible.

As first shoot the following procedure is suggested. One or two very advanced world regions reach nearly zero emission by 2100 or have at least emission levels below 10 % of the 2000 values. In the rest of the world the emission trend could be reversed at least from 2070 onward. Emission levels do decrease. Adjusting the emission levels will then part of the back-casting development and strongly depend on the events that are assumed to happen.

3.2 The nuclear issue

Nuclear is a rather controversial issue as regard sustainability. Connexions between civil and military uses of nuclear are strong, and existing nuclear weapons could almost destroy all life on earth. Radiotoxicity of nuclear wastes can last as long as several thousands of years, creating a permanent threat on future human beeings, which is exactly at the opposite of sustainability principle, at least on its ethic dimension. But mastering the nuclear energy is also a tremendous chance for the human kind to abolish the resource and environmental burdens that fossil fuels put on the human development for this generation and many of those to come.

Two main principles

Nuclear energy used for generating heat and electricty today, maybe hydogren tomorrow, is defenitely not sustainable as it is today, for the reasons explained above. This has led several industrialized countries either to refuse any development of the nuclear energy, or to stop it after some development (the USA in the seventies), or even to adopt a moratory in order to close the existing plant before the end of their normal life (Germany, Sweden, Belgium,…). Strong pressures are put on many developping countries to stop any attempt to develop this energy.
Today's nuclear energy is intrinsically not sustainable. This is the first principle to be admitted, otherwise there is no limit to be put on the development of the nuclear energy, at least as much is needed to cope with other environmental sustainability criteria.

The second principle is that nuclear energy could be made sustainable, thanks to technological development likely to make it possible to break the link between civil and military uses, and to destroy the very long term radiotoxicity of the nuclear wastes or to eliminate such wastes. Obviously transmuting or fusion belong to these categories. This principle has also to be admitted, otherwise there would be no future for nuclear in a sustainable world.

Contribution to socio-economic development

If nuclear is to be sustainable, there cannot be any more objections for any country to have access to nuclear, making this country escaping to the environmental and economic burden that increasing scarcity (and then rising prices) and carbon content (and then rising limits on

quantities) of fossil fuels will put. In that respect, it could certainly contribute to a faster and long lasting socio-economic development (in the broad sense) of the planet.

But what means the fact that any country may have access to nuclear?
First, the unit sizes of nuclear units should be compatible with most of the sizes of the national energy grids, which means that gigantism, as today, is not necessary anymore (neither from economic nor technical viewpoints; this does not means that very big machines necessarily disappear, but are adapted for very big markets).
Second, the control of nuclear operations safety should not be different from any other industrial activity, and should not impose any particular organisation and governance of the society beyond what is currently accepted in democratic industrial societies.

The global and local environment concerns

Sustainability does not mean that nuclear should become totally harmless, but that immediate industrial risks may be balanced with immediate socio-economic benefits in the one side, and that reducing long term environmental burden can be balanced with immediate socio-economic efforts in the other side.

The first industrial risk, with possible long term environmental consequences, comes from accidents in current operations (Three Mile Island, Tchernobyl,…). Sustainability imposes first that no very long lifetime radiotoxic elements could be ever released in any accident configuration. Once this is admitted, the size of the risk which is accepted is a matter of democratic choice within each country, and of international negociations (including the admitted lifetime of radiotoxicity).

The second industrial risk comes from wastes proccessing and storage. Sustainability imposes first that no very long lifetime radiotoxic wastes should be stored “for ever”, however the storage is operated. As for nuclear operation, it imposes also that no very long lifetime radiotoxic elements could be ever released from waste processing in any accident configuration. Once this is admitted, the transition between the existing nuclear industry, which is definitely not sustainable, and the long term sustainable solutions, is a matter of democratic debate: is it acceptable, to which point, to continue non sustainable nuclear operations for a while, if this appears to be a condition for sustainable nuclear to happen? Should future sustainable nuclear solutions necessarily solve the sustainability problems heritated from the today’s nuclear?

The security concerns

Although historically civil and military uses of nuclear have been closely connected, countries or groups of people can purchase or build today nuclear weapons without developping a civil nuclear programme. This is a matter of wealth and of independence and/or power demonstration. But this is possible because of the way nuclear energy is exploited today in other countries, and because the former linkages with military purposes in those countries. Should the linkage be broken in sustainable nuclear options, then no element of this nuclear option could be used anymore to build any weapon, and dissemination of weapons from this side would stop. Of course nuclear weapons will still be constructed, and will remain definitely a vital threat for the human kind. But the international control on these weapons would be probably much easier if none of them could emerge from the civil nuclear.

Terrorism is another security concern linked with sustainability. Unfortunately, terrorism might co-exist with sustainability, but under the conditions that the consequences of terrorism, as bad as they can be, do not violate the sustainability principle. In that respect, terrorism enters in one of the two sutainability issues considered above, accidents and nuclear weapons, and does not raise any other specific problem as regard sustainability.

Proposal for criteria

We can summarize the various consideration above with proposals for qualitative criteria to define what sustainable nuclear solutions should be:

1 - No major accident “physical possibility” (i.e. accident releasing significant quantities of long life radiotoxic elements)
2 - No proliferation “physical possibility” (i.e. no bridge between civil and military applications)
3 - A zero long-lived high level waste inventory
4 - A real contribution to development (i.e. accessible for all)

Agreeing on these criteria for 2100 would probably not raise any problem.
The key questions are elsewhere: what to do with the existing nuclear technology in between? To which extent the operation of these technologies could continue, although they are not sustainable, if future sustainable solutions can solve the problems created in between?

To answer these questions, without establishing restriction criteria for intermediate points which would sharply restrict the use of nuclear for the next 60 years (these cases will be covered anyhow elsewhere), we propose to define some milestones of R&D developments as requirements for sustainability. Only if it was proven by demonstration plants, that plutonium can be “burnt” efficiently a further extension of nuclear is consistent with a sustainability strategy and certainly if enough capital is available to construct the “burners” later on.

As shown in VLEEM 1, Pu-burners will not be available for decades, but it would be sufficient to have them commercially available around the fifties to get rid of the stockpiles of Pu (and hopefully also of all other actinides and the long-lived fission products) up to the end of the 21st century by extended application of such (future) actinide-destroyers. Another approach would be to rely entirely on Thorium-based cyles for the long run, but such cycles need their long R&D-time either and would not speed up the actinide destruction. Possibly the future actinide stockpiles could be a bit smaller.

Suggestions for scenario storylines

The main guidelines for including nuclear sustainability issues in scenario storylines could be the following:

- the more wealthy the region, the more fulfilled the economic and financial conditions for R&D on sustainable nuclear options and for sustainable nuclear investment;
- the more severe the CO2 constraints, the more flexible the attitude towards continuation of existing non sustainable nuclear and transition towards sustainable nuclear;
- the more diversified the world cultures and modernities, the more likely the development of nuclear.

3.3 Other environmental issues

Other environmental issues relate to sustainability, although less crucially than nuclear or green-house. Among them, three devote some further attention: the increasing use of land for energy activities, which could challenge the use of land for feeding the world population at some point; the release of local pollutants which could have disastrous effects on health and soils in a distant future through accumulation processes; industrials risks beyond those specific to nuclear, which could threat large amounts of population more or less irreversibly.

Infrastructures and land-use

Two major examples of the threat that energy infrastructures and land –use can put on large population are, first, the food deficit of Brazil which was provoked by the production of sugar can for substitution of alcohol for gasoline on the best agricultural area; second, the displacement of one million people because of the gigantic “Three Gorges” hydroelectric installation in China.

More generally, here is the main sustainability problems of renewables, the necessary large occupation of land, due to the usually very low density of the natural energy flows.
Trying to set ex-ante quantitative limits to the km² that renewable energy collection should not overcome is nevertheless meaningless, for at least two reasons: multi-utilisation of space (solar roofs on houses for instance), necessary differentiation in criteria according to the type of land (or sea) used (off-shore versus in-shore wind farms for instance).

Instead, we will consider in VLEEM that priorities have to be set in the use of land in view of sustainability: first agriculture and food production, second urbanisation and transport, third forestry and natural space for human well-being and for biodiversity, and then industrial activities including energy. Space requirement for renewables on-shore should necessarily consider these priorities (including whenever relevant the multi-utilization of space).

Air pollutants

Periodically, global environmental problems emerging from the accumulation of local pollutants appear, and are more or less well resolved: HFC’s and the ozone layer destruction, acid rains and the deperishment of forests in Canada, Scandinavia, Siberia,….More recently, the brown cloud covering for months the whole south and south-east Asia, from Pakistan to the Philippines and Irian Jaya raises fears about possible massive drawbacks on the health of billions of people.

The main difference with green houses gases or nuclear is that these unsustainable consequences are not intrinsically linked to the energy carriers which are produced and used, but on the technical conditions in which the production and use are done. Acid rains result from the SO2 released by the fuel combustion, but it is absolutely possible to burn any fuel without releasing any SO2. The same for NOX, CO, etc…

Therefore, we can hardly consider that fossil fuels or biomass raise sustainability problems because of local pollutants which cannot be solved except by reducing the quantities. This is a matter of improving the technical specifications of the products and the techniques to produce

and use these products. VLEEM will point out these necessary improvements, but will not set any sustainability criteria or indicator on this respect.

Industrial risks

By other industrial risks related to energy activities, which raise question as regard sustainability, we understand: the pollution of the seas and oceans by hydrocarbons, threatening various life species among birds and water resources, and part of the alimentary chain; the depletion or poisoning of fossil natural water resources in relation to geological consequences of energy mining activities; the use and poisoning of surface water resources by energy production activities, creating a threat on water availability and aquatic life; etc…

Again, technical solutions to these risks do exist, and sustainability problems are created by the way energy is produced and used, not by the essence of the energy products themselves.

As for local pollutants, VLEEM will point out the problems and these necessary improvements on this respect, but will not set any sustainability criteria or indicator .

Suggestions for scenario storylines

To summarise, only the question of land-use calls for a special attention within VLEEM, as regard sustainability.

But no quantitative criteria can be set. VLEEM will provide information on the sustainability dimension of the land-use issue within the scenarios.

The main guidelines for including land-use sustainability issues in scenario storylines could be the following:

- the more severe the CO2 constraints, the more attractive the renewables, the less stringent the "natural space preservation" component of the land-use;
- the more populated the planet, the less space available for renewables;
- the more diversified the world cultures and modernities, the more opportunities for renewables but the more diversified the positions of "natural space preservation" component of the land-use.

3.4 Resources issues

The availability of the resources is a fundamental stake of sustainability. The problem of the resources exhaustibility concerns, in particular, four resources.
Firstly, the impoverishment of the soil. Indeed, the agriculture intensification involved the degradation of 38 % of the 1,5 billion hectares of the planet's cultivated area until 1990 (that is to say 562 million hectares) and this degradation has been continuing since 1990 by 5-6 million hectares by year. 50 % of the wetlands and 90 % of the pastures thus disappeared during the last century, as well as vast forest surfaces (their surface decreased from 11,4 km2/cap in 1970 with only 7,3 km2/cap currently).
The second resource concerned is the biological diversity. The overexploitation of the fishes and shellfishes concerns about 70 % of the principal species' world reserves.

The third stake is the availability of fresh water. Indeed, world water consumption increases by 2-3 % per year, whereas the use of the fresh water resources is already faster than their renewal rate.
Lastly, fossil fuel resources are also exhaustible. If we consider only the ratio reserves/production, the oil proved reserves makes it possible to cover only 44 years of production, 60 years for gas and coal 200 years.

We will concentrate hereafter on the problem of the depletion of fossil fuels and more particularly the oil and gas exhaustibility. The empirical and theoretical points of view of the specialists will be firstly exposed, then the geopolitical stakes related to oil.
In principle, renewable resources are not concerned by the problem of the depletion, but as we will also see, their exploitation raises other sustainability problems.

Depletion profiles for oil and gas

§ Oil and gas production will peak before the turn of the century

The eventual scarcity of fossil fuels energies and in particular of oil and gas is in the centre of an important debate. In the one hand there is a "pessimist" way of thinking essentially driven by geologists like Laherrere, Campbell, Ivanhoe and Hubbert who think that there should be a peak of the oil and gas production quite rapidly (in the next 10 years for oil). In the other hand, a group of "optimists" which is represented essentially by economists like Adelman, Lynch and Odell who think that the oil and gas peak of production should appear latter (about 2040 for the oil production).

The point of view of the main long term energy-environment models is disparate, the divergence being induced by the uncertainties.

- The Illustrative or Marker scenarios presented in SRES, the Special Report on Emissions Scenarios of the IPCC (IPCC, 2000) forecast a peak of the oil production between about 2020 and 2080, depending on the hypothesis of the storylines. This peak will be between 2050 and 2080 for gas production.

- According to the reference scenario of the IIASA-WEC study (Scenario B), the peak of the oil and gas production should not be achieve before 2050, but there will be a very strong slowdown of the oil production between 2020 and 2050.

- The Shell Scenarios ("Exploring the future; Energy Needs, Choices and Possibilities-Scenarios to 2050") are the most pessimist. They forecast that the scarcity of oil supplies should be between 2025 and 2040 depending on the adoption or not of known measures to increase vehicle efficiency and focus or not of the oil demand on this sector. Gas production should peak between 2025 and 2050.

- Finally, according to the International Energy Agency, world oil production would not peak before 2030 but non-OPEC production is expected to peak at just under 48 mbl/d around 2010. This scarcity of non-OPEC crude oil will be compensate by OPEC production which should grow from 38% in 2000 to 54 % in 2030.

Even if all the specialists don't agree with the exact date of the peak, all are sure that oil and gas production will peak before the turn of the century. This raises two major questions as

regard sustainability: for our generation and the next ones, the peaking in hydrocarbons production may raise enormous socio-economic difficulties worldwide, and major international tensions; more distant future generations would not benefit at all of natural hydrocarbons.

§ Economic theory and depletion of exhaustible resources

The fundamental question raised by exhaustible resources as regard sustainability is whether or not the price of these resources and its evolution can reflect properly the two dimensions of the problem, production peaking for these generations, and availabilities for more distant future generations.

Regarding this question, the economic theory is dominated by two opposed approaches. In the one hand, the "weak sustainability" defended by the Neo-Classics' way of thinking and in the other hand the "strong sustainability" (The first vision, developed during the 70's, before the publication of the Brundtland's Report, don't mentioned the term "sustainability" but actually deals with this subject).
Both approaches are based on the same idea that the sustainable development implies, for the actual generation, to increase the available financial, human and natural capital. But the difference between the two is that, in the "strong sustainability" vision, the substitution between the three types of capital is considered impossible, whereas it is considered possible in the other vision

The origin of the "weak sustainability" vision is the principle developed by Harold Hotteling about the fixing of prices scale for exhaustible resources published in 1931 in the article "The Economics of Exhaustible Resources". The Hotelling rule began with a work about the optimal management of a mining layer. The owner of such a resource naturally wishing to maximize the present value of his future profits, wants to find the optimal extraction rate and the better trend of the selling price.
So, the Hotelling rule means especially that, on the one hand at the equilibrium the price is compounded by a "scarcity rent" which correspond to the "marginal cost of use" and, on the other hand, the price increase in such manner that, in T', when the resource is totally depleted, its level imply a demand equal to zero.

The "weak sustainability" theory, developed particularly by Hartwick (1977), Dasgupta and Heal (1979) rule is based on the equity criteria between two generations published by Robert M. Solow in 1974. This criterion is that the per capita consumption of the resource has to be constant across the time in such manner that no generation is favoured related to an other. That is to say, the objective is to determine the most fixed level of per capita consumption being able to be maintained taking into account all the existing constraints, among which the depletion of the resource. They base their analyse on the assumption that there can be a substitution between the natural and the manufactured capitals and that the technological progress can overcome the environmental constraints of the economy: it will "save the day".
So, for the Neo-classics, there are three rules which permit to attain this criterion:

- Totally use the available financial capital and labour
- Respond to the Hotelling rule
- Invest in reproducible capital (for example of the machines) the rents and the profits obtained by the exploitation of the exhaustible resource

However, this theory was criticized a lot. Two main limits are generally exposed. The absolute substitutability between the capital, the labour and the natural resource is not always true. Indeed, if the elasticity of substitution between the exhaustible resource and the other factor of production is lower than one and if the elasticity of the production related to the reproducible capital is lower than the elasticity of the production related to the natural resource the criteria is not achieved. Moreover, if technology is going to save the day, it is no incentive to protect and conserve resources today.

The second vision, the "strong sustainability", is more recent (90's) and is not based on the absolute sustainability of the three factors of production. According to this vision, natural capital is necessary to make manufactured capital and natural capital fulfils other economic functions, including basic life support, that manufactured capital cannot fulfil. Daly (1991), which is an important architect of this vision, highlights two qualitative rules related to sustainable development and the depletion of resources[13]:

- The utilisation rate of non-renewable resources should not exceed the development rate of their substitute
- The utilisation rate of the renewable resources should equal their regeneration rates.

Common and Perrings (1992), pursued to develop this theory. For them, the concept of ecological sustainability is very different from that of economic sustainability. They integrated biological and engineering parameters in production functions and psychological parameters in utility functions. The main conclusion of their study is that economic efficiency is not necessary for ecological sustainability and can also conflict with it.

- **Questions related to the theory**

Whatever the economic theories considered, they are all largely based on the adjustments on the market prices and the behaviours of the resources owners.

Concerning the adjustment on the market prices, we can anticipate that there will be a gradual adjustment mechanism between the supply and the demand by the oil and gas prices. Indeed, whatever the energy, the decrease in the production in parallel of a constant or an increasing consumption will involve a rise in the energy prices on the markets, which imply a decrease in the demand. Moreover, this rise will permit the development of other profitable technologies whereas it was not with lower oil or gas prices.

So, one can consider that the market could "solve" the problem, at least as regard production peaking, but the question remains whether the transition towards alternative energies could be progressive and "natural" or not. That is to say if oil and gas price signals will be high and soon enough for alternatives to be ready earlier than the expected oil and gas production peaks, pushing oil and gas away (peaks in production would therefore mainly result from decreasing demands, whatever the situation of the reserves); or if oil and gas production will start decline for geological reasons, forcing consumers to fight for increasingly scarce resources and to adapt through crisis.

[13] Daly, op. cit. He exposed also two other rules related to the sustainable development. One is linked with the soil resources and say that harvest rates should equal regeneration rates. The other is related to the wastes : the waste emission rates should equal the natural assimilative capacities of the ecosystems into which the wastes are emitted.

- **Who owns the resources, who decides depletion rates**

The liberal economic theories all suppose that the owners of the exhaustible resources behave so as to maximize their profit over the duration of the exploitation of the resources. In other words, depletion rates are supposed to be entirely determinated by the price evolutions and expectations.

But can we assume that all owners of exhaustible resources will behave like that? Liberal economic theories probably grasp relevantly the behaviours in western industrial societies (where they have been elaborated), but this is a matter in which cultural values do play a significant role.

Would some major oil producing countries (Saudi-Arabia, Iraq, Iran, etc…) behave differently and adopt a restrictive approach of the depletion (adapt the depletion rate to the needs of today, keep resources for future generations, etc…) , the peaks in production may happen even earlier than expected, shortening the delays for transition.

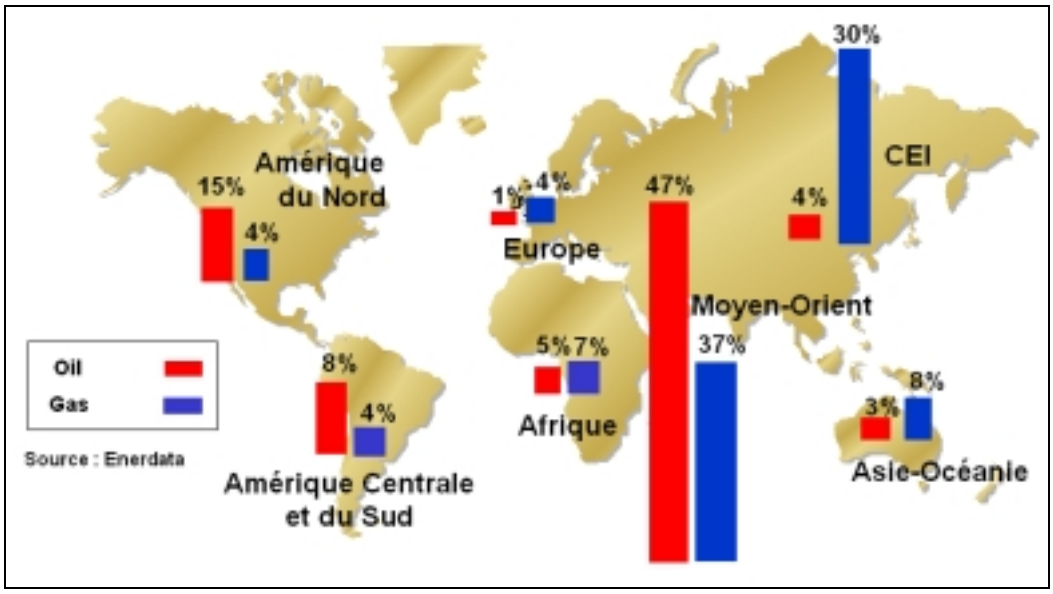

Figure 1: Repartition of oil and gas proved reserves by region

Oil/gas resources location and geopolitical threats

It is necessary to take into account another factor of unsustainability linked with the depletion of the oil and gas resources : the geopolitical threat. Indeed, three issues related to the geopolics of oil and gas resources have to be considered.

First, the peaking and decrease of the oil and gas production will appear earlier in politically stable countries (US, Canada, Norway, UK, Mexico, Brazil) than in politically unstable regions (Algeria, Libya, Egypt, Sudan, Nigeria, Angola, Russia, Former soviet republics in Central Asia, Indonesia and Venezuela). This phenomenon will increase the dependence of oil and gas consuming countries on these unstable regions. Moreover, The concentration of resources in these countries will also be a problem for countries that own the resources.

Indeed, the issue of who should control the resources (and related revenues) is a part of the problem, especially if nationalistic aspirations are strong. These two consequences should multiply the number of war involved by oil and gas resources issues. Indeed, we have experienced already that oil (and gas) are factors of war. (Golf War in 1991, Iraq war in 2003,...) .

Second, during this century, the OPEC countries and more precisely those around the Persian Gulf will become more and more important world swing producers of oil. So, they will have a heavy impact on the price that we will pay for the resources and on the resource depletion path. But, as shown by the graphic below, when the pressure on the OPEC capacities becomes too important (around 30-35 Mb/d), there is a crisis. So, the question is whether a future increase of the contribution of OPEC to the world oil production will necessary lead to new crisis like in the past, or if, as suggested by international long term energy forecast (IEA, IIASA, WETO), there will be a regular rise in the market prices.

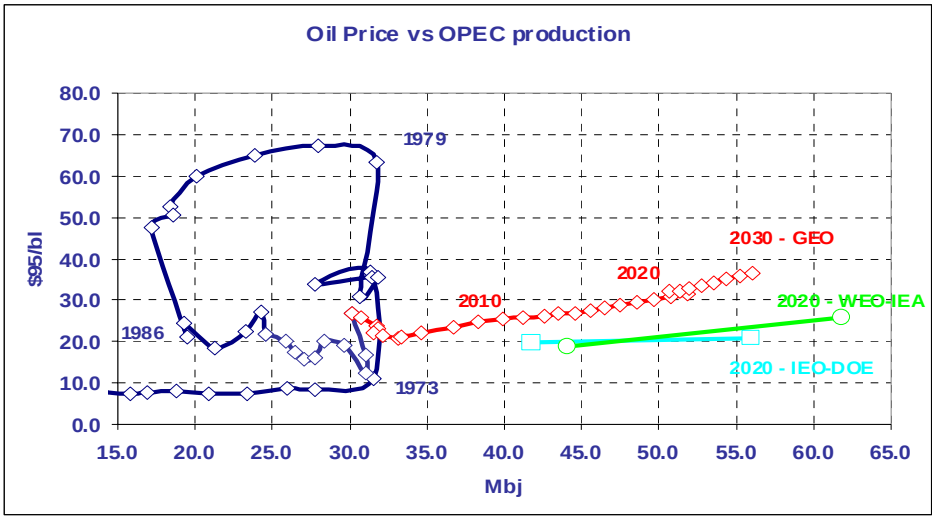

Figure 2 : Oil prices versus OPEC production (Source: P. Criquis, EPE)

Third, the long term strategies of China and India will be critical. Indeed, the graphic below shows that, according to WETO[14] , Asian imports, which were lower than North American imports in 2000 will be multiplied by 5 by 2030, and then, represent about the double of the sum of the other regions' imports. Only a dramatic increase of the Gulf exports would be able to respond to this strong increase in the oil demand.

[14] EC, « World energy, technology and climate policy outlook 2030", EUR 20366, Brussels 2003

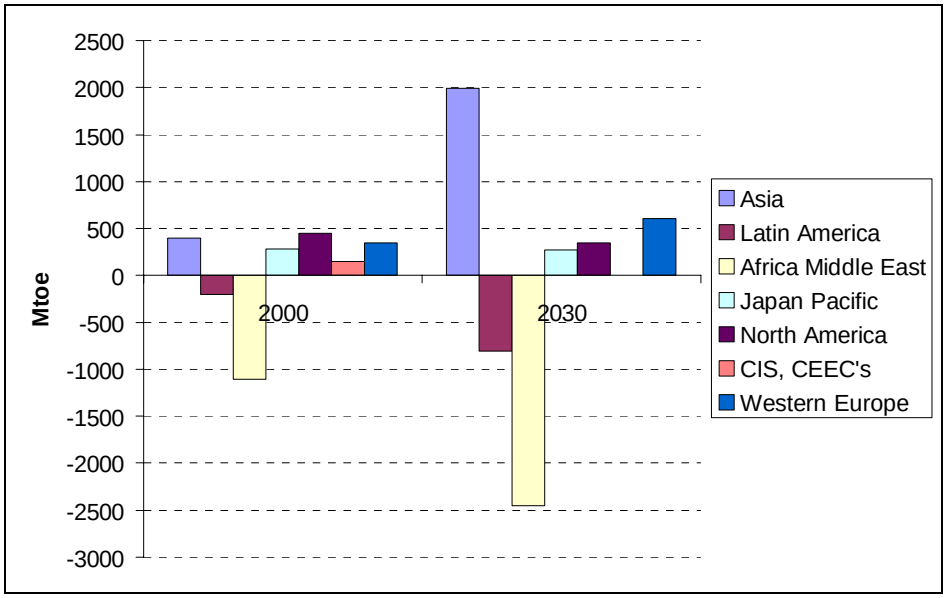

Figure 3 : Oil and Gas imports and Exports (Source: WETO, European Commission)

Are renewable resources harmless?

Renewable energies like hydro, biomass, wind, solar, geothermal and wave energy do not raise the same sustainability problems as oil or gas. But renewable does not mean infinite! Harvesting these natural resources means installations which occupy space and which cannot deliver more energy than the nature provide by m² or by m3. The larger the needs, the bigger the use of land, the more visual and acoustic effects.

As discussed above, land-use is in itself a sustainability problem if it conflicts with more important priorities like food production for instance.
But another sustainability problem is raised by renewables, in particular from an ethic viewpoint, if the development of renewables has hardly reversible consequences on land and human settlement. This is already the case with many hydroelectric installations, this might become the case with biomass (as regard future biodiversity) or solar electricity or wind power (because transmission lines).

Suggestions for scenario storylines

Sustainability would certainly suggest that alternatives to oil and gas should be ready and available in large quantities before the expected “business-as-usual” peaking of oil and gas production, decline of oil and gas production resulting therefore from a declining demand. This means either that (sustainable) socio-economic conditions are fulfilled for the oil and gas demand to increase slowly (appropriate demographic, cultural and macroeconomic assumptions), or that efficiency in the use of oil and gas would increase strongly, or both. This means also that unconventional resources of oil and gas would be tapped as much as possible.

The lower the demand, the higher the unconventional resources exploited, the further the “BAU” peaking of oil and gas production. Should these peaks occur after 2100, scenario

storylines based on the continuation of the hydrocarbon era could be used to describe sustainable energy systems at the turn of the century.

100% renewables by the turn of the century is probably not sustainable as regard land-use and other ethic problems. Most probably sustainability discussion around the renewables will turn around a trade-off between less green-house gases and more space and visual/acoustic aggressions from renewable installations. Again, within an agreed emission level of green-house gases, sustainable levels for renewables will have to be discussed within the various scenarios and their related energy demands.