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VLEEM 2

MID-TERM ASSESSMENT REPORT

Main report

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Content

1 - Analytical & Knowledge developments

1.1 Accounting for sustainability in VLEEM (WP1, task 1.1)[1]

Back-casting is the back-bone of the VLEEM methodology. This innovative approach of the very long term is strongly connected with the concept of sustainable development, or more generally with a concept of a desirable future.

In VLEEM the energy related needs are assessed with a forecasting philosophy, through general but simple causal relations with demography, wealth and life styles. Back-casting 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 realized. 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?…

1.1.1 Socio-economic viability and sustainability of energy systems

As a matter of fact, the concept “development” , as applied exclusively to economics and measured exclusively by the GDP, cannot pretend neither to cover the whole social and

[1] The comprehensive synthesis of the developments about accounting for sustainability in VLEEM constitutes the annex 1 to this report

economic dimensions of sustainability[2], nor even the issue of the necessary conditions for "enough" acceptable personal and social life.

Instead, Indian Economics' Nobel Price, Prof. A. SEN proposes a broader definition of human welfare[3], 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.

Demography and economic growth

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[4]" 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.[5]

Beyond its key role in the economic growth, demography raises also questions as regards social relations: inter-generations coexistence, multi-racial, multi-culture coexistence, etc…

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

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[2] 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)..

[3] **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.**
[4] 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.
[5] CEPII, « INGENUE » model
[6] E. Todd, « Après l'Empire »

positions; at the same time, fertility rate goes 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.

We are not willing to consider that very long term stability of the world population is a pre-condition for sustainability, although fluctuation in fertility rates and population over the very long range may create inevitable turbulences within all world regions, and migrations among world regions.
Instead, 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, and 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.

Cultures, life styles and consumption patterns

Migrations, another key issue as regards future social and economic conditions, 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.

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 sutainability:

- 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,

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 empire and the US cultural model? Or with that of China? Or with that of other regional blocks? 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?

Welfare and social equity

Linking welfare to HDI respond to VLEEM request for an operational concept integrating social and environmental concern, as well 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 regards the evolution of relative levels of HDI, for sustainability purposes, is that the existing gaps across the world will not enlarge.

1.1.2 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.

Climate change

The climate change debate is strongly coupled to the debate about sustainable development. It might turn out that the emission of CO2 will become the most important environmental sustainability indicator. This said, 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. The IPCC as body implemented by the UN environmental programme tries to give answers to these questions. But the IPCC 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.

Nuclear

Nuclear is a rather controversial issue as regards 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 beings, 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.

Nuclear energy used for generating heat and electricity today, maybe hydrogen tomorrow, is definitely not sustainable as it is today, for the reasons given above. This has led several industrialized countries either to refuse any development of the nuclear energy, or to stop it after some development. Strong pressures are put on many developing countries to stop any attempt to develop this energy.
But we have to admit that nuclear energy can be made sustainable, thanks to technological development likely 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.

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.
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 negotiations.
Sustainability imposes second 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.

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 developing 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, an issue already considered above.

Other environmental sustainability 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.

Land use is the main sustainability problem of renewables, because 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 set priorities in VLEEM 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).

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,….. 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. 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.

By **other industrial risks** related to energy activities, which raise question as regards 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 the necessary improvements on this respect, but will not set any sustainability criteria or indicator.

Non-renewable energy ressources

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). All consider that oil and gas production peaking will occur before the end of the century.

The fundamental question raised as regards 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”.
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 is based on the concept of 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.

The second vision, the “strong sustainability”, is more recent (90’s). 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[7]:

- 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.

Whatever the economic theories considered, they are all largely based on the adjustments on the market prices and the behaviours of the resources owners.
Oil and gas prices will rise along with the increasing discrepancy between production and demand trends, which in turn will result in a decrease in the demand trend. This rise will permit the development of alternative profitable energy carriers and technologies.
So, one can consider that the market could “solve” the problem, at least as regards production peaking, but depending when the peak will occur, the transition towards alternative energies can be progressive and “natural” or not. Therefore two cases are possible and must be considered as regards sustainability:

a) 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);
b) oil and gas production will start to decline for geological reasons, forcing consumers to fight for increasingly scarce resources and to adapt through crisis.

[7] 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.

1.2 Energy services & energy demand (WP1, tasks 1.2, 1.4; WP2, task 2.2)

1.2.1 Demography and Macro-economics (task 1.2)

Macro-economics and time-budget

The main theoretical assumption supporting the macro-economic representation in VLEEM is that the growth of the wealth on the very long term is driven by two fundamental drivers only: the total volume of hours for paid work and the information level. This is how demography/time-budgets in the one side, education/information in the other side are related to macro-economics.
The evolution of the structure of time-budgets according to socio-cultural functions is driven by three exogenous influences:

- decrease of the time allocated to the food-feeding function with time;
- number of paid work hours per year and in the life-time
- access to tertiary education.

Time-budgets for "shelter and lodging" and for transport are assumed constant. Time budget for "self-accomplishment" is assumed to balance the 24 hours a day.

The development of the research work on the development of the transport system over the very long term (PhD thesis of Vincent Bagard; see above 1.1 and annex 2 for theoretical developments) has pointed out two major facts that oblige to reconsider how the development of the wealth interact with the time-budgets:

- first, the investigation of the relation between the time allocated to self-accomplishment and the time allocated to transport obliges to revisit the initial assumption that the time-budget for transport would remain constant for ever: this is a matter of value of time and cost and utility of leisure commodities related to self-accomplishment, and might change slightly over the very long term;
- second, according to Becker, Linder and others, more generally the evolution of the time-budget results fundamentally from two basic drivers:
    - the value of time, which is determinated by the level of the hourly salaries, which results from the productivity improvement, i.e. information level in VLEEM representation;
    - the increase in consumption opportunities with the wealth (and productivity), the cost of goods and services involved in consumption opportunities (which result from labour cost and productivity) <u>and the time involved in the consumption activity.</u>

It is not our purpose to formalise in VLEEM how wealth will change the time-budget structure. Nevertheless, these theoretical developments obliges to modify slightly the representation of the changes in the time-budget structure in the future, and to consider more explicitly the influence of wealth on the structural assumptions. Here are the main enhancements:

- in "food-feeding" function, accounting for a limit in the decrease of the time-budget which results from the fact that the time saved by new equipment devices, new food products and new services is more and more offset by the additional time requested for the maintenance of the equipment devices [LINDER, 1970];

- in “shelter and lodging”, accounting for a regular increase in the time budget resulting from increased time for the maintenance of the dwelling, provoked by an unavoidable more rapid growth of the cost of maintenance services than affluence [LINDER, 1970] ;
- in “self-accomplishment”, accounting for the consequences of the development of the leisure outside home (“escapades”) on the overall time-budget for transport [BAGARD, 2003];
- in “paid work”, accounting for the trade-off between the value of time for new leisure activities and the level of hourly salaries[BAGARD, 2003].

Demographic transitions, macro-economic equilibria and actual economic growth

VLEEM considers first the potential growth of the economy on the basis of the potential volume of labour hours and level of information. The actual growth is derived from the potential one through an assumption about how much of the potential could be actually exploited. This assumption was assigned to capture all barriers and problems which could explain why the actual growth might be slower than the potential one (financial problems, restrictions to education or to access to work, lack of entrepreneurs, etc…).

Although we consider that VLEEM should not turn into a macro-economic model, we are nevertheless aware of the weakness of this representation, in particular on two aspects:

- the relations between the changes in the demographic structures and the macro-economic equilibria, and their possible consequences on actual gross capital formation and actual employment;
- the relations between the changes in the demographic structures, the regional financial requirement/capabilities, and the gross capital formation and actual employment.

In order to address the first aspect (macro-economic equilibria), we have formalised some very basic accounting formula related to the formation and use of wealth in the one side, related to the relation between the overall macro-economic quantities such as consumption, salaries, net profit,…and the structure of households according to cohorts in the other side.
These formula allow to simulate how a change in the distribution of households according to cohorts (in particular because of the demographic structure evolution) modify the share of the final consumption of households and administration in the wealth (if nothing change in the relative consumption levels according to cohorts), and by consequence the share of gross capital formation. On the reverse, they also allow to assess how the relative consumption levels should change to maintain the overall consumption/gross capital formation balance.

The impacts of the change in the balance consumption/ gross capital formation on the employment are assessed through a second set of formula based on the two following principles:

- in order to maintain a certain level of employment, there is a minimum gross capital formation requested; this minimum depends on the level of employment and increases with the wealth per employee;
- beyond the minimum requested to maintain the employment, any additional gross capital formation results in an increase in the volume of employment according to

a ratio gross capital formation per employee which increases with the wealth per employee.

These equations allow to simulate how a change in the overall consumption/gross capital formation balance could result in a decrease, a slower increase or an acceleration in the overall employment. Such an information, combined with the simulated progression of the total active population, results in an indication to which extent the potential growth (based on the active population, i.e. potential employment) could be exploited.

To address the second aspect (financing), we have incorporated in VLEEM the theoretical concept of the INGENUE model [Aglietta & alii,] which formalise the overall relationship between the demographic transition and the macro-economy worldwide on the very long term. A set of formula has been designed to balance the total savings of the households, the profit and the financial requirement for gross capital formation.

They allow first to simulate how a change in the households structure according to cohorts would change the global financial balance of the region, ceteris paribus.

Reversely, they allow to find out which changes in relative consumption levels, in relative salaries and/or salaries versus profit would be compatible with an equilibrated overall financial balance.

Finally they allow to simulate possible retroactions of financial constraints on the overall balance final consumption / gross capital formation in the wealth. In that last cases, the previous set of formula will indicate the consequences on the employment and the actual progression of wealth.

The details of these formula and preliminary results are displayed in annex 3.

1.2.2 Transport system of the future and "self-accomplishment" (task1.4, 1.5)

The initial assumption regarding passenger transport in VLEEM was that the time budget for transport was constant, one hour per person per day in average. This assumption was based on Zahavi's results [ZAHAVI,] and validated by further results of research works carried out very recently in France [LET, 2002] and the USA []. In fact these results concern only usual day-to-day transport activities, in the usual urban environment. The time spent in long distance transport was up till now too marginal (in average terms: time per person per day) to alter these results.

The research work carried out by V. Bagard in his PhD thesis highlights two facts that could modify this perception of the stability of the transport time, in line with the theoretical propositions and equations of Becker []:

- all consumption of goods and services, and working for money, involve time and, for those outside the home, transport ; the time spent in transport is a fraction of the time spent in consumption or working activities (so-called alpha coefficient), the level of which is related to the utility of the time spent;
- among the services, those related to leisure outside home, in particular "escapades" for week-ends and holidays, benefit increasing time-budgets with higher values according to "exotic" non tangible aspects when income increase; as a result the alpha coefficient related to the consumption of these services increases as well, resulting in the following consequences: an increased number of "escapades" in the year, less time spent for each of them, an increased alpha coefficient and an increased speed to allow consistency between time and distance (for "exotism").

As long as we consider that time is not storable, and that people cannot save their current daily life time for increasing their time for "escapades", then we have to conclude that the overall time budget for transport might increase in the distant future. Is this increase significant enough to escape from the marginality (as compared to current daily life transport time) considered up till now? May be; but here is not the problem that we have to address. What could make a fundamental difference as regards our first approach is that the current daily life transport time corresponds to distances and speeds that are mostly determined by urban/suburban conditions. But transport time for escapades involve much more considerable and increasing distances and speeds which could modify significantly our appraisal of the needs of energy services related to transport in the very long term, even if the time involved in "escapades" averaged per person and day remains very small.

We do not intend to formalise in VLEEM the Becker's equations which allow to describe all the mechanisms briefly described above. These equations can nevertheless be found in a preliminary paper of V. Bagard, "La dynamique du temps de loisir", in annex 4. Instead, we have limited the scope of the existing passenger transport module of VLEEM to the daily life transport (i.e. with adequate distances and speeds); then we have attached to the modelling of the energy services of the "self-accomplishment" function, a transport module related to "escapades", for which time-budget, distances and speeds are appraised consistently with the value of time (i.e. wealth created per working hour).

1.2.3 Data issues (tasks 1.6, 2.2)

Demography and Socio-economy (task 1.6)

Three types of data are use to supply the Vleem model:
Transverse sources: Enerdata database, World Bank, FAO, Measure DHS
National sources : National statistical institutes, ministries, diverse studies
Estimations when there is no available data

The sources of the data detailed by module are presented in the tables below.

Demography

Type of data	Source
Survival probabilities	World Bank
Fertility	World Bank
Population by class of age	World Bank
Households by number of person	National data

Information Indicator

Type of data	Source
Enrolment in primary, secondary and tertiary school	Measure DHS, OECD, National data and Estimations

Activity

Type of data	Source
Retirement age	National data
Maximum labour activity levels by type of person of the household (head of the household, other, children)	Estimated from World Bank
Maximum labour activity levels by type of household (single household, single household with one child, two persons without child, more than two persons)	Estimated from World Bank

Time budget

Type of data	Source
Labour	World Bank
Food & feeding	National data and MTUS database
Transport	Estimated: 1 hour per day
Shelter and self accomplishment	Estimated

Production

Type of data	Source
No input	

Food & feeding system

Type of data	Source
Households	
Useful energy consumption	National data
Needs of energy services	Estimated
Production	
Useful energy consumption	Enerdata
Needs of energy services	FAO

Shelter

Type of data	Source
Households	
Useful energy consumption	National data
Needs of energy services	Estimated
Dwelling production	Estimated

Self accomplishment

Type of data	Source
Useful energy consumption	National data
Needs of energy services	No input

Transports

Type of data	Source
Stand by	

A big part of the data come from reliable sources, but as VLEEM need very precise and technical data, an important part are not supplied by transverse or national sources and are not always reliable. In particular:

- differentiation between data for rural and urban regions
- data about dwelling production (use of energy to produce one ton of material and how average necessary quantity of material to produce a dwelling)
- households equipment and energy consumptiondata for the Sub-Saharan Africa region

A questionnaire have been prepared and sent to different organisations in some principal countries of the main regions were there is a lack of information (see annex 3) . The results have been rather poor up till now, this type of information being rather difficult and time consuming to obtain.

Validation of the demographic module for the ten VLEEM regions

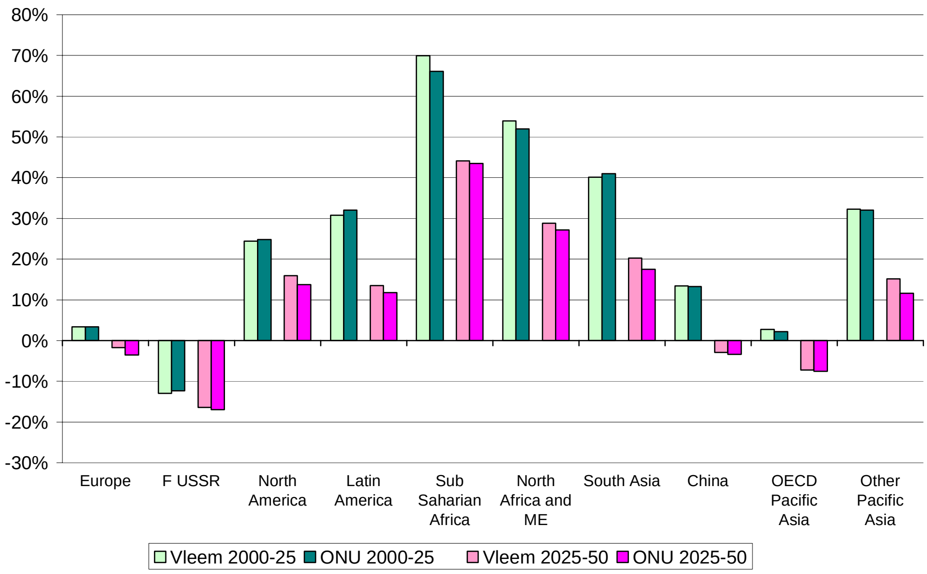
Concerning the demographic module, the work was done in two steps. Firstly, it consisted to applying the demographic module developed for the European region to each of the ten

Vleem regions and to validate the results provided by the module by comparing them with other projections. Secondly, a simulation of the first results was done in taking into account different scenarios.

The validation of the demographic model for the ten VLEEM regions was done by comparing the principal results of the model with the simulations of the "medium variant" of the United Nations "World population prospects (2002 revision)[8]" in taking into account the same fertility and migration assumption as the United Nations. The comparison was done concerning the number of birth, the number of death, the growth rate of the urban population, the growth rate of the rural population and the differentiation between the different classes of age for each region[9]. The simulation of the United Nations is done until 2050, so the validation was made only until this year[10].

The results obtained are generally close to those of the United Nations and involve simulations of the growth rate of the total population very close to those of the United Nations (Figure 1). We can consider that the global methodology of the Demographic module is validated and that the module is able to provide rather reliable first results.

Figure 1: Comparison between the population growth rates simulated by VLEEM and the United Nations model between 2000 and 2025.



Industry (task 2.2).

Production data: The main source used for VLEEM is the UN Production Statistics of Industrial Commodities, CD-ROM Database 1950-2000. This database covers all countries in the world, and all commodities over a 50-year timescale. In practice, the bulk materials

[8] http://esa.un.org/unpp/
[9] The United Nations do not provide results about the urbanisation rate for the Sub Saharian Africa region, so the validation was not possible
[10] The United Nation do not provide results about the urbanisation rate after 2025, so the validation was made only until this year

needed for this research usually were available from the late 70's up to 2000. For most industrialized countries, data was available for at least part of the time-series 1980-2000. For developing countries, data availability proved to be difficult for some products, especially for brick and glass. Materials that have been the subject of research already for a longer time (of which steel is an example), usually have a better data coverage than other materials. In the specific case of steel, data was available from the 1960's. In the table in appendix 1, an overview is given of the data that was used from this UN database, combined with the availability of trade date.
At first, we tried to cover all regions as described in the VLEEM model description by using representative countries for these regions. However, since data for the production and trade of bulk materials in these representative countries was not always available or very often not comparable, we extended our research into all countries that had both production and trade data available. In doing so, we create a broader basis for deriving the relationship between per capita consumption and per capita income.

Trade data: Data on trade of the selected bulk materials, for the countries available and the timeframe 1980-2000 was purchased from the UN Statistics department (UNCTAD). These data were usually available in monetary and physical terms, only the latter ones have been used.

Apparent Consumption: For the calculation of apparent consumption, the following formula was used:
$AC = P + (I - E)$
Where:
AC = Apparent Consumption
P = Production
I = Imports
E = Exports,
(All values in physical units)

Unfortunately, for the calculation of the AC, the availability of the time series for production and trade did not always match. This limits the amount of (historical) data points for the time series on apparent consumption.
For the analyses on the relationship between per capita consumption and per capita income, we used historical population and GPD data from the IEA. Population data was available in thousands (persons) for the period 1980-2000, for all countries. GDP data was available for 1980-2000 and all countries as well, and was expressed as 1995 US$ based on purchasing power parities (ppp)

After analyzing the relation between per capita material consumption and per capita income, the second step in our analysis was to investigate the use of the bulk materials by type of application. Therefore, we collected data on the shares of material by type of application from various sources. The main sources for these data were sector representative organizations (APME, CEPI, IISI, EAA, CPIVGLASS).

Future data.
To prepare projections for the future use of bulk materials, the extra data we used were forecasts for population and on GDP. The GDP and population scenarios until 2100 are taken from the IPCC Socioeconomic Data from (IPCC Data distribution Centre); the data that will be generated by VLEEM will be used later on.

In order to prepare projections for the future energy use (in absolute terms), the other part of our research was to identify the potentials for improvement in the specific energy use (SEC) for the production of bulk materials. To this end, we collected data from key-literature sources commonly used in this type of bottom-up analysis [de Beer, MARKAL documents, LBNL studies, BAT reference documents and specific sector studies]. Usually, per material investigated, several sources were available that gave indications for the performance of the SEC in the year 2020 and 2050.

Using these data, we determined the best-fit trend for the specific energy use up to 2050 as projected in bottom-up analyses. Since for the period 2050-2100 there are no indications on the performance of technologies (or even the kind of technologies used), we assumed that in the period 2050-2100 the SEC could be reduced by 1/3 of the gap to the thermodynamic minimum for the base-case (standard technology development). For technological paradigms where it may be possible to achieve larger efficiency gains, we assumed that on top of the aforementioned reduction, another reduction of 1/3 to the thermodynamic minimum would be possible.

Table 1: Data coverage of production and trade data of bulk materials in several countries.

Country	Cement	Steel	Paper	Polymers	Aluminium	Fertilizers	glass	brick	Wood
Algeria	*	X		*	-	O2	X	X	
Argentina	-	X			X	X			
Australia		X				O2			
Austria	O1	X			X	O2	O1	O1	
Bangladesh						*			
Belgium	*	X		*	-				
Brazil	O2	X		O2	O2	X[2)]			
Bulgaria	*	X		*	-		*		
Cameroon	-	O2			*				
Canada	O2	X		O2	X	X			
Chile		X				O2	O2		
China	O2	X		*	O2	O2	O2		
Colombia	X	X		*	*	X[2)]	*		
Costa Rica						O2			
Croatia						O2	O2	*	
Czech Republic	*	O2		*	-	*	*[1)]	*	
Denmark	X	X		*	O2	X	*	*	
Egypt						O1	X		
El Salvador						*			
Finland	X	X		*	O1	X[2)]	O1	*	
France	-	X			X	X	O1	O1	
Germany	O2	X		*	O2	O2	O2[3)]	O2[3)]	
Greece	X	X		O1	X	X	O1		
Guatemala						O2			
Hungary	*	X		O2	*	O2	*	*	
India	X	X			X	X	*		
Indonesia	X	X			*	O1	O2		
Iran	*	X			*	*	*		
Ireland	X	X			-	X			
Italy	-	X			X	X	X	*	
Japan	X	X			X	X	X		
Kenya							*	*	
Luxembourg	*	X			-				
Macedonia						*	O1		
Malaysia						X			
Mexico	-	X			*	*	*		
Morocco						*			

Netherlands	X	X		*	X	X[1)]		O2	
New Zealand						X			
Pakistan						*			
Peru						*	*		
Philippines						X	*		
Poland	X	X		X	X	X	X	O2	
Portugal	X	X		X	X	X	O1	X	
Republic of Korea						X	X		
Romania	-	X			O2	*	O2		
Russia	-	O2			*				
Senegal						O2			
Slovakia	*	O2		*	*	*	O2	-	
Spain	X	X		X	X	X	O1	X	
Sweden	O2	X		O2	X	*	X	X	
Switzerland		X				X			
Syrian Arab Republic						*	X		
Thailand						*			
Tunesia	O1	X			*	X	X	-	
Turkey	O2			O2	O2	O2	X		
UK	X	X		X	O1	*	X		
Ukraine	-	*			*	*		*	
USA	X	X			X	O1	O1		
Venezuela	O2	X		O2	O2	O2			

X = timeseries 1980-2000 (almost) completely available
O1 = timeseries of at least 1980-1990 was available
O2 = timeseries of at least 1990-2000 was available
* = only few years were available
- = No data available
polymers/glass : no data for all products available
[1)] = Formula AC = P + (I-E) resulted in negative AC
[2)] = Some years missing
[3)] = for Fed Rep Germany also 1980-1990 available

1.2 Technologies and energy services (WP3)

1.2.1 HydroPower development with a focus on Asia and Western Europe (tasks 3.1, 3.2)[11]

Introduction

It is often assumed that the importance of natural gas for the world's energy use could increase until 2020, starting from the current use of oil, coal, natural gas, nuclear, hydropower, etc. However, hydropower could also be increased in view of depletion of gas reserves, political factors (hesitations with regard to nuclear power), and environmental reasons (global warming).

Hydroelectric projects can include dams, reservoirs, stream diversion structures, powerhouses containing turbines, and transmission lines. Reservoirs behind dams often provide other benefits, e.g. recreation, flood control and navigation, irrigation, and municipal water supply.

According to the World Commission on Dams (WCD), more than 45,000 large dams have played an important role in harnessing water resources for irrigation, power generation, flood control and domestic water use. Hydropower has a share of 19% in global electricity generation. Also, 30-40% of irrigated land relies on dams, and ca. 800 million people benefit from food produced by dam related irrigation. Therefore, a closer look at the potential of hydropower makes sense. The study 'Hydropower development with a focus on Asia and Western Europe' (ECN-C-03-027) from ECN Policy Studies and Verbundplan offers such an analysis.

Main features of hydropower and definitions of potentials

Hydropower plants either are based on reservoirs or are run-of-the-river plants. A run-of-the-river plant draws the energy for electricity generation mainly from the available flow of the river. Such a hydropower plant generally includes some short-term storage (hourly, daily, or weekly), allowing for some adaptations to the demand profile. Typically, the average generation (firm capacity) of a run-of-the-river plant is 55 to 60 percent of the rated power.

In order to reduce the dependence on the stochastic inflow, many hydropower plants feature large reservoirs and corresponding dams. All hydroelectric reservoirs of the world together cover an area the size of France. These storage plants have compact turbines, thereby lowering the construction cost. They can be started up and shut down very fast, making them the technology of choice for following the demand, generating peak power, controlling the frequency, and providing fast start-up reserve. These qualities become especially valuable in systems with a high share of intermittent renewable electricity generation.

There are several classifications related to the dimension of hydropower plants, e.g.:

- Micro hydro: <100 kW
- Mini hydro: 100 - 500 kW

[11] Details are available in annex 7

- Small hydro: 500 kW - 50 MW
- Large hydro: >50 MW.

Hydropower stations may have capacities in the GWs, with turbines up to 700 MW each. The largest hydropower station under construction is the 18,200 MW Three Gorges Dam in China.

In the literature several types of hydropower potentials may be found:

- The (gross) theoretical potential, based on computations of the potential of water flows, without taking into account technical, economical, and environmental constraints.
- The technically feasible potential or the net exploitable potential. This is the amount of hydropower that could be developed from a technical point of view. Economical and environmental constraints are not considered.
- The economically feasible potential. This is the amount of hydropower that could be developed based on economical constraints. Environmental constraints are not considered explicitly.

The world's technical hydropower potential

Hydropower may have reached a mature state of development in most OECD countries, but there is still a huge potential in developing countries (Figure 1). Concerns about environmental impacts and land requirements for reservoirs have recently constrained multilateral assistance in hydropower development. However, both developmental needs and environmental and social concerns should be considered carefully. Hydropower is a time-tested source of electricity that is relatively free of greenhouse gas (GHG) emissions. In ecological terms, hydroelectricity has many advantages now that considerable efforts are made to reduce GHG emissions.

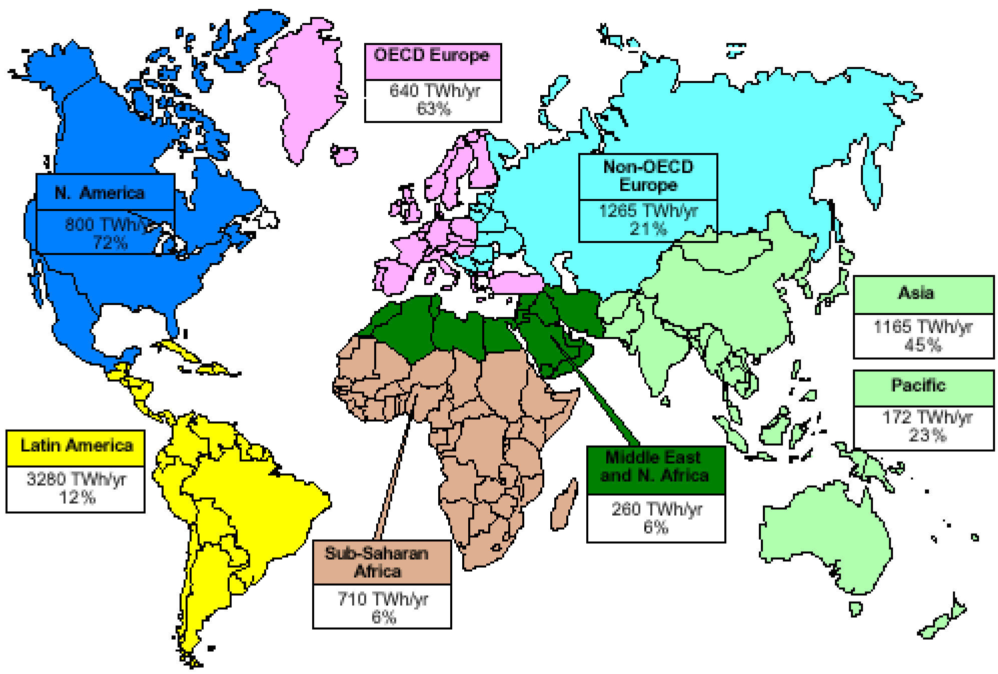


Figure 1 *Net exploitable hydropower potential (TWh/a) and percentage exploited*

Hydropower development by world region

There are many and sometimes huge hydropower projects under construction or planned in several world regions (Table 2).

In the US and in most of the countries of Western Europe new large-scale hydropower plants are generally not accepted for environmental reasons. The focus is on upgrading of hydropower plants or on relatively small hydropower projects.

In Eastern Europe the focus is on modernisation and upgrading of hydropower plants.

Table 2: Hydropower capacity under construction or planned in selected world regions

Region or country	Commissioning date	Hydro under construction or planned [GW]	[% of installed hydro capacity]
Canada	2003-2012	>6.6	>10
Mexico	2007-2012	5.7	59
Central America	2003-2016	4.4	~100
South America	2003-2010 (and beyond)	34.9	30
China	2002-2020	77.7	94
India	2003-2014	>11.6	>46
Nepal	2003-2010 and beyond	20.5	4770
Pakistan	2003-2010 and beyond	>7.1	>1770
Myanmar	2003-2010 and beyond	7.0	1800
Vietnam	2003-2016	5.7	137
Africa	2003-2010 and beyond	9.0	43
Turkey	2003-2009 and beyond	>3.6	>29

A key feature of investments in hydroelectric power generation projects is that they require long-term loans with extensive grace periods because they are capital-intensive, have a long construction phase with significant risks and have a long useful life. The average construction costs of hydropower plants are between \$ 1,100/kW (China, Latin America) and \$ 1,400-1,800/kW (Africa, India, Turkey), with exceptions both of higher and lower construction costs.

The generation costs especially for older hydropower plants are very low. On average the generation costs are less than a third of that of coal, oil, gas or nuclear, when considering all real costs for the latter.

Limits for hydropower: environmental problems

The past has shown that hydroelectric power plants especially in large-scale projects can bring a lot of problems:

- Hindering the fish by blocking fish moving up the river to the spawning grounds.
- Decreasing of wildlife in river grounds and former rain forests by flooding.
- Dislocation of people for dam projects, e.g. in case of Three Gorges Dam (China) 1.13 million people.
- Oxygen reduction in the water by rotting of flooded vegetation killing fish and plants.
- Emission of methane after rotting. Methane is a strong greenhouse gas that has 21 times more effect than CO_2.
- Dissolving of natural metals from stones and soils (e.g. mercury) after flooding.

- Water quality (oxygen reduction) and sedimentation problems (filling) by reducing the flow speed.
- Problems for fish population as a result of flushing for clearing sedimentation.
- Stranding fish in shallow water areas by power plant operation.
- Potential dam breaking (war, earthquakes).

Solutions for these problems are:
- The environmental questions of hydropower systems must be compared with the effects of the alternatives (acid rain, global warming, etc.).
- Leaving untouched smaller and wild rivers.
- Integration in nature planning.
- Fish-friendly solutions.

Small and large-scale hydropower

On a global scale, the relation between small hydropower (including mini/micro) and large hydropower was 1:20 (115 and 2,260 TWh, respectively) in 1995. For the year 2010, this relation is expected to be 1:18 (220 and 3,990 TWh, respectively).

In countries with a presently high share of small-scale hydropower plants, this share is expected to stagnate or even decline. Only in areas dominated by big hydropower projects today, the future will bring an increased market penetration of small hydropower (Table 3).

Table 3: Ratio between small and large-scale hydropower generation

	Ratio between small and large-scale hydropower generation	
	1995	2010
Europe	1:10	1:11.5
Asia	1:7	1:10
Latin America	1:132	1:100

Source: Internet source 4

Conclusions

On a global scale, hydropower is an important renewable energy source. In the long term, it will meet increasing competition from ‘new’ renewables (wind, solar, biomass, etc.). Whether a specific hydro project will be developed or not, depends not only on the economic benefits, but also on the environmental impacts (positive and negative). Sometimes, the environmental and social impacts of (large) hydropower projects may be substantial. However, thermal power generation and nuclear power also have their drawbacks. Global climate change seems to be the main threat to biodiversity and food production. In this context, the issue is to what degree will society accept some local impacts of hydropower, in order to mitigate the global impacts of climate change and other environmental risks from thermal power generation (coal- or gas-fired power).

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1.2.2 Biomass

Using biomass (or fuels or wastes derived from biomass) as a source of energy entails burning it to yield heat that can then drive engines or generate electricity. The energy in biomass is chemical in nature; it does not suffer from the problem of intermittence that is inherent to wind and solar resources. In this respect, biomass more nearly resembles fossil fuels than it does other renewables. Indeed, geologists tell us that fossil fuels are simply fossilized biomass.

For most of recorded history, biomass was mankind's principal energy source, mainly in the form of wood used for cooking and heating and as foods to "fuel" human labor and beasts of burden. With the industrial revolution, fossil fuels captured this dominant role. Today biomass still accounts for 15% of worldwide primary energy consumption, but, significantly, the fraction is much higher in developing nations than in developed ones.

Biomass today accounts for over one third of all energy used in developing countries. It has been called "the poor man's oil" because its direct use by combustion for domestic cooking and heating ranks it at the bottom of the ladder of preferred energy carriers. Existing biomass-using technologies are relatively inefficient; thus, biomass provides less energy service than the proportion of total energy it represents, and women and children in rural areas spend considerable time collecting daily fuelwood needs. Biomass energy use today also contributes to indoor air pollution and associated negative health impacts. Furthermore, most biomass energy today comes from natural forests, contributing to deforestation in some countries.

Table 4: Total biomass supplies for Energy(Ej/year) for the RIGES

Total Biomass Supplies for Energy (EJ/year) for the Renewables-Intensive Global Energy Supply Scenario (RIGES)

	YEAR 2025				YEAR 2050			
REGION	Forests	Residues	Energy Crops	TOTAL	Forests	Residues	Energy Crops	TOTAL
Africa	2.43	6.81	18.94	28.18	2.43	9.38	31.81	43.62
Latin America	1.59	10.92	32.30	44.81	1.59	13.59	49.60	64.78
S&E Asia	3.13	13.61	—	16.74	3.13	20.42	—	23.55
CP Asia	1.21	3.85	5.00	10.06	1.21	4.16	15.00	20.37
Japan	—	0.89	—	0.89	—	0.95	—	0.95
Australia/NZ	0.02	1.14	—	1.16	0.02	1.39	—	1.41
USA	0.61	5.86	9.60	16.07	0.61	5.68	9.60	15.89
Canada	0.04	1.43	1.20	2.67	0.04	1.42	1.20	2.66
OECD Europe	0.31	4.85	9.00	14.16	0.31	4.86	9.00	14.17
Former CP Europe	0.58	5.28	4.00	9.86	0.58	5.68	12.00	18.26
Middle East	0.02	0.18	—	0.20	0.02	0.23	—	0.25
TOTAL	9.94	54.82	80.04	144.80	9.94	67.76	128.21	205.91

Source: T.B. Johansson, H. Kelly, A.K.N. Reddy, and R.H. Williams, "Renewable Fuels and Electricity for a Growing World Economy: Defining and Achieving the Potential," Chapter 1, pp. 1-71, and "A Renewables-Intensive Global Energy Scenario," Appendix to Chapter 1, pp. 1071-1142, in T.B. Johansson et al. (eds.), *Renewable Energy: Sources for Fuels and Electricity* (Washington: Island Press, 1993).

Biomass has the potential to provide a much higher level of energy services in developing countries, in environmentally friendly ways, if the production and conversion of biomass is modernized. A recent assessment of the potential for renewable energy, prepared as input for the U.N. Conference on Environment and Development (UNCED), found that sustainable biomass energy systems could be the largest single contributor to global energy supply; the study found that under a "Renewables-Intensive Global Energy Scenario" (RIGES), biomass could provide as much as 35 per cent of the total demand for primary energy in 2050 (see Table 4). A "sustained growth scenario" developed by the Shell International Petroleum

Company's Group Planning Division found biomass' potential contribution to total energy supplies in 2050 to be similar (about 210 EJ- Exajoule is 1018 joules).
Such visions of large contributions by biomass to global energy supply are plausible because ongoing technological advances offer the promise of being able to turn biomass into more desirable forms of energy (such as electricity and liquid and gaseous fuels) in ways that are both environmentally friendly and economically competitive with fossil fuel alternatives. These technological advances are of comparable significance to the fundamental technological developments (steam turbines and internal combustion engines) that were largely responsible for the expansive growth in global fossil fuel use that began late in the nineteenth century.

In the RIGES, the majority of biomass energy supplies come from high-yielding energy plantations covering some 430 million hectares worldwide, or an area equivalent to roughly one fourth the area currently used for agriculture worldwide. Africa and Latin America would be the two largest biomass producing regions.

Biomass Potential

Because populations are growing, an important question is whether there are sufficient land resources to both feed future populations and sustain the magnitude of biomass energy development implied in the RIGES and the Shell scenario.

Using Degraded Lands for Biomass Energy
To help insure a minimum of competition between agriculture and energy production, a number of analysts have proposed that developing countries target degraded lands for energy production. Grainger and Oldeman et al. have estimated that developing countries have over 2,000 million hectares of degraded lands, and Grainger estimates that some 621 million of these are suitable for reforestation. This is consistent with estimates that previously forested area suitable for reforestation amounts to 500 million hectares, with an additional 365 million hectares available from land in the fallow phase of shifting cultivation.

Worldwide interest in restoring tropical degraded lands is growing, as indicated by the ambitious goal of a global net afforestation rate of 12 million hectares per year by 2000, set in 1989 at the Ministerial Conference on Atmospheric Pollution and Climate Change. This is comparable to the rate at which biomass energy plantations would have to be established in the first quarter of the twenty-first century for Africa, Latin America, and centrally planned Asia to meet the goals envisaged in the RIGES.
Energy industries might provide the capital needed to finance land restoration activities since advanced biomass conversion technologies like gasifier/gas turbine systems are expected to be highly economically attractive. In principle, energy industries would have an incentive to restore lands in sustainable ways because they would require secure supplies of biomass feedstocks throughout the lifetimes (twenty years or more) of their capital-intensive investments in energy conversion facilities. Such supply security could be assured only if the plantations were managed sustainably.
The main technical challenge is to find a sequence of plantings that can restore ground temperatures, organic and nutrient content, moisture levels, and other soil conditions to a point where crop yields are high and sustainable. It appears feasible to overcome this challenge. Other difficulties that must be surmounted reflect general conditions in many developing regions, for example, complex or disputed land ownership, lack of roads or other means to transport biomass to processing facilities and biofuels to markets, and the fact that

growers in poor areas cannot wait the three to eight years that is typically required for cash returns on short-rotation tree crops. Despite these technical, socio-economic, political, and other difficulties, however, proof of the potential for growing energy crops on degraded lands can be found in the many successful energy plantations that already exist in developing countries.

Nevertheless, intensive research, development, and implementation programmes are needed to accelerate the rate of plantation development. Such programmes should lead to the development of region-specific restoration plans that take into account local bioclimatic and socio-economic conditions. Restoration activities involving both outside experts and local farmers should be investigated. Also, restoration plans that can lead to commercial energy crops should be demonstrated. Such demonstrations might be conducted as joint ventures among local agricultural producers and equipment supply firms, local and multinational energy companies, and local and international organizations interested in land restoration.

Biomass – Pretreatment and First Conversion

Biomass shows a relatively low energy density (see table 5) leading to an extended supply area and relatively high transport costs. These transport costs approximately double the raw biomass costs of 6 to 12 US$/MWhbiomass /i/. Considering also the relatively low 20 % electrical efficiencies of biomass power technologies, biomass power generation units should be smaller and more dispersed than conventional thermal power generation units.

Table 5: Energy density of different fuels	
Fuel	Energy density in GJ/m³
Fuel oil	35-40
Hard coal	22-25
Wood chips	2.5-4
Wood pellets	10-14
Straw chipped	0.5-0.8
Straw pellets	6.5-10.5
Cattle excrements (liquid)	1.3-1.7

Biomass Combined Heat and Power

A number of conventional and innovative technologies for a combined heat and power production from biomass is currently under investigation:

- The steam turbine process (STP),
- the steam engine process (SEP),
- the steam screw engine process (SSEP),
- the organic Rankine cycle (ORC) process,
- the Stirling engine process (StEP),
- the direct (inverse) gas turbine process (DGT),
- the indirect (hot air) gas turbine process (HAT),
- the solid bed gasification + gas engine or fuel cell (SBC+GE),
- the fluidized bed gasification + gas turbine (FBG+GT).

Biomass Cofiring

Co-firing is the simultaneous combustion of biomass and fossil fuels. The advantages of co-firing are:

- leveling of (seasonal) fluctuations in biomass supply;
- stabilization of fuel heat value;
- increase of power plant capacity /i/;

- the low additional investment costs of about 400 US$/kW /[ii]/;
- biomass with a water content of up to 69 % can be utilized without drying;
- the product gas does not need to be purified prior to combustion;
- the gasifier can be operated down to 50 % of full capacity;
- an electrical efficiency for the biomass to power conversion of 38 to 40 % is achieved.

Biomass Power Plants

The focus of developments for large scale biomass power plants lies with improvements of the IGCC process. One design concept of biomass IGCC, is the TPS-process. This process is based on two circulating fluidized bed reactors (a biomass-gasifier and a tar-cracker). A 8 MWel TPS plant is currently constructed in Yorkshire/UK. Other concepts, like the VEGA process of Vattenfall or the Värnamo plant of Sydkraft AB feature pressurized gasification. Further demonstration plants are under operation in Hawaii (the fuel is sugar cane residues) and in Vermont (with wooden residues as fuel) funded by the US department of energy Biomass Power Program, and in Brazil funded by the World Bank.

Biogas

Anaerobic fermentation is the wet conversion of agricultural or communal residues by certain bacteria to biogas, a mixture mainly of methane and carbon dioxide. Solid biomass like wood or straw show a very slow biodegradation rate. That is why biofermentation of this kind of biomass is not economic.

Different fermenter types are commercially available. Usually fermentation is performed in a totally mixed reactor. Mesophilic bacteria achieve maximum conversion rate at temperatures of 30 to 40 °C, thermophilic bacteria at 50 to 60 °C. As heat source for keeping the fermenter at the optimal temperature, 15 to 30 % of the produced biogas is used. For the generation of 1 kWh power and 1.24 kWh heat 5-7 kg bio-waste, 5-15 kg municipal waste, 8 to 12 kg cattle waste or 4-7 m^3 organic waste is required.

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2 – Modelling development (WP4)

2.1 Background: the back-casting methodology in VLEEM

2.1.1 Introduction

The back-casting methodology will be sketched at first. The methodology is only expanded to the technological part of the energy system. The organisational aspects of the energy system are subsumed under the technological aspects. The real driving forces namely life-style and population growth are dealt with in a forecasting or more descriptive fashion. This means no measures to control life-styles or population growth will be presented as possible solutions.

The methodology is performed in two major steps. Design of an end-point, which fulfils certain criteria and then the back-casting step. Both steps include formal and more qualitative procedures. The methodology will shortly be reviewed in part 1, while part 2 will describe the software tools under development, which will later on guide the analysis.

2.1.2 End-point design

The end-point is designed according to special requirements, which are derived from sustainability objectives. For practical reasons these objectives will be formulated in the form of criteria or simple procedures. Possible criteria, restrictions or procedures were already discussed before. Environmental aspects are only one perspective, social and economic requirements will also be respected. The end-point should be seen as an extreme point in the development, when changes to a sustainable system could be considered to be complete or are close to be completed. This end-point differs certainly from "business as usual" scenarios. Choice of the year 2100 as end-point is certainly arbitrary. It offers on the other side the opportunity to realise major changes even on a global scale. Identification and exploration of chances is the major argument for a back-casting approach and the major challenge of this study.

2.1.3 Back-casting

Back-casting is well suited to analyse trajectories into a sustainable future, or more general into a desired future (VLEEM I).

Formal aspects: Technological performance, Resources, Environment and Diffusion

Some aspects have to be formalised, even if the overall analysis is partially kept on a more qualitative level:

- technological performance of technologies
- diffusion patterns of technologies
- amount and distribution of resources
- overall environmental impacts, like CO_2 emissions

The **technological performance** will be characterised with a bundle of parameters. Prominent examples are efficiencies, energy flows of renewables or the ability to access certain resources. The performance depends certainly on the information available. It will be a challenge for VLEEM to have one concise and consistent definition of the term information.

Diffusion pattern – also in principle determined by various factors – can still be described in a rather formal way, especially if a global perspective is envisaged. In this phase of VLEEM diffusion pattern will only be captured by restrictions of growth rates. The way these growth rates are formulated offers the opportunity to model different political and economic world situations. In a co-operative world only the overall global development is restricted, in a world of various blocks, the individual growth rates will be restricted and will be independent of each other.

Availability and distribution of **resources** is in principle open to quantitative descriptions. Again the absolute amount depends certainly strongly on the information level reached.
The data collected in VLEEM I regarding this question will be utilised in parallel to common data sources like the data base of the USGS and BGR.

The same can be said about **environmental impacts**, which are mainly open to quantitative statements, like the amount of CO_2 emissions, the land used and so on.

Milestones driving the development

The central part of the analysis will be the identification of major events and milestones within the development. This part of the analysis is certainly more qualitative. The result will more look like a history text book. Still it is necessary to have some quantitative approach. Three event and milestone types will be distinguished:

- general social, political and economic settings (examples are the possible conviction to sustainability or liberalised markets)

- major investment decisions and organisational arrangements in the energy sector (agreement of oil companies for an additional fuel for cars, investment in new infrastructure, ...)

- major unalterable events (depletion mid-point of oil, climate change), they are of cause only unalterable at the time the happen, by different strategies before they could be avoided (like in the case of oil by a more restrictive use before)

The first two events are decisions done by various actors on various levels, the third class of events are causal effects on these decisions. They are the result of model runs or of more general reasoning. This procedure is chosen to highlight the fact that developments in economy and industry are not in total determined by general laws, but by individual or collective decisions. This very general approach needs some formal restrictions at least for the beginning. A list of major actors and of major strategies followed by these actors will be sketched at the beginning.

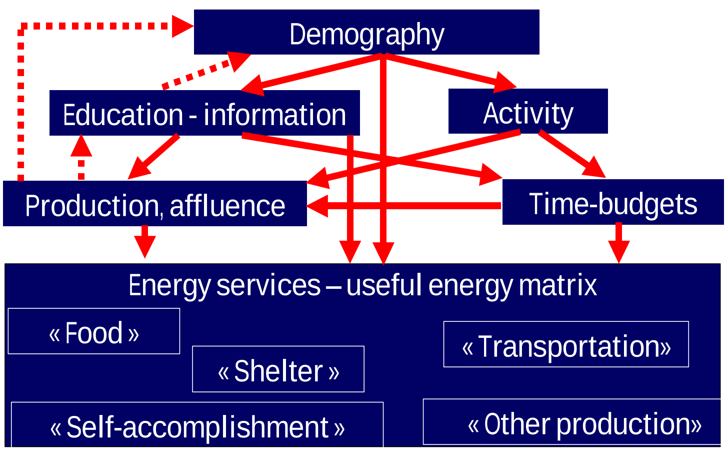
A simplified example should illustrate the procedure. Major milestones would be a rather early break-through in the exploitation of gas-hydrates around 2010. Of course this would be the result of major R&D undertakings in this area before. Technological developments would make gas-hydrates economic viable around 2025, heavy coal economies are all redirected towards gas, even the transport sector is mainly fuelled by gas hydrates by then. Climate change policies could be fulfilled until 2050 by the complete replacement of coal – with few exceptions in steel industry. From then on CO_2 sequestration has to become a major option. Incentive to follow this line is the fact that the gas hydrates can be harvested at reasonable costs. Debates on the best CO2 storage options have already before let to the qualification of various options. In a first step exploited oil and gas fields and deep coal seems are used, but after 20-30 the limitation of the storage capacity becomes obvious. Intense R&D in between opens the path to a very safe storage of CO_2 as carbonates. The conversion to carbonates can only be done close to certain mineral rocks, but the very refined gas-pipeline infrastructure, which can also be used for hydrogen, makes the transport of gas from hydrates and of hydrogen possible.

The sketched development would first be triggered by a technological break through, namely safe and simple methods to exploit gas-hydrates. The event would dominate the later development completely. This technology would certainly alter the complete energy system. Energy prices would be dictated by the gas hydrate price and no longer by the oil prices. Very intensive R&D programmes would be launched to "decarbonise" the gas and to find safe and ample storage for the produced CO2.

2. 2 Needs of energy services – BASES (task 4.1)

2.2.1 Background

BASES (BASics of Energy Services) is the sub-model of VLEEM dealing with the very long term projections of the needs of energy services for all world regions.
The general structure of BASES as resulting from the previous development within the VLEEM 1 project is as follows (more details available on the VLEEM web site: www.VLEEM.org):



Up till now, the programming of BASES has been undertaken in the Excel environment, with one file per world region plus one for the whole world.

In VLEEM 2, BASES has been improved in three basic fields:

- macro-economics foundations and related formalisation of the blocks "Time-budgets", "activity" and "Production, affluence";
- theoretical foundations of the transport module and related formalisation of the blocks "Time-budgets" and "Energy services - Transportation";

- conversion of BASES in C++ environment and implementation of the connections with the other sub-models of VLEEM.

2.2.2 Enhancement in formalisation

The modelling enhancement is based on the theoretical development explained above (1.2.3)

Time budgets

Here are the main changes:
- in “food-feeding” function, accounting for an exogenous limit in the decrease of the time-budget ;
- in “shelter and lodging”, accounting for a regular increase in the time budget with affluence;
- in “self-accomplishment”, accounting for leisure activities far away from home (“escapades”) and transport time-budget dedicated to these activities in addition to the constant daily transport time budget;
- in “paid work”, accounting for the trade-off between the value of time for new leisure activities and the level of hourly salaries.

Demographic transitions, macro-economic equilibria and actual economic growth

Formalisation of the macro-economic accounting formula within VLEEM-BASES:
- wealth = consumption of households and administrations + gross capital formation
- wealth = net salaries + net profit + intake operated by the state
- household consumption per household = weighted average of consumption per households cohort (according to age, etc…)
- salary per household = weighted average of salaries per households cohort (according to age, etc…)
- in each cohort: consumption per household = salary per household + transfer per household – savings per household
- intake operated by the state = transfers to/from households + net consumption of administration (outside salaries of civil servants) + public investment.

Formalisation of the relation between gross capital formation (GCF), employment and ratio actual/potential growth
- if GCF>min GCF, increase in employment = (GCF-minGCF)* additional employment/unit GCF ;
- if GCF<min GCF, decrease in employment = (minGCF- GCF)* employment/minGCF ;
- ratio actual/potential = employment / active population

Formalisation of the financial accounting formula within VLEEM-BASES:
- in each cohort: savings per household = salary per household + transfer per household – consumption per household
- households savings = sum of savings per household per cohort * number of households per cohort
- overall financial balance = households savings + net profit + overseas financial transfers + other net savings – gross capital formation

The details of these equations and preliminary results are displayed in annex 3.

Transport

An additional passenger transport module is added to the former one, based on the same logic (relations between time budget, speed and distances, in relation to affluence) and formalisation, to account specifically for transport activities due to “escapades” and related energy services.

2.2.3 Software development

VLEEM-BASES has been first programmed in the Excel environment. It is being converted into a compiled C++ software, according to the following principles:

- conversion of the formula in C++
- management of data in text files
- user interface almost identical to what is available in the Excel environment, both for data input and for the visualisation of results
- linkage with other sub-models of VLEEM (mostly TASES and BALANCE) through text files.

2.3 Demand for Energy Carriers – DACES (task 2.1, task 2.3)

The demand for energy carriers is determined by making forecasts for the physical activity in 2100, combined with estimates for the energy efficiency of the processes related to these physical activities (so, energy use per ton of steel, energy use per kilometer traveled, energy use per dwelling for space-heating, and so on).
The total energy demand depends also on forecasts on the population and the wealth of people in the different regions distinguished in VLEEM. These data will be taken from the results from the BASES model. The details of DACES developments are in annex 5.

2.3.1 Bulk materials

In analyzing the future energy needs for the production of bulk materials, two major drivers are important: The amount of material produced, and the specific energy needed to produce 1 ton of material (the so-called SEC, specific energy consumption). These two factors combined together give an indication for the amount of energy that will be needed in the various regions of the world for the material production system.
In our analyses, we have included the following materials:

- Iron and Steel
- Aluminium
- Pulp&Paper
- Polymers
- Cement
- Fertilizers
- Bricks & Roof tiles

- Glass
- Wood

Finally, to link up with the material demand categories in the VLEEM model, an analysis on the shares of materials by type of application is needed. In that way, we can analyze the demand of energy for the production of packaging materials, building materials, infrastructure materials, fertilizers and other bulk materials.
The methodology for these three steps has been briefly explained in Section 1.2.3 and is described in more detail in annex 5.

2.3.2 Transportation

Freight transport

Special emphasis has been put on the transportation of base materials for the production of bulk materials, since the forecasts for bulk materials production are available from the analyses on bulk materials (Section 2.3.1) use.
For the energy needed for transportation of base materials, we have followed a very basic approach. Current lifecycle assessment (LCA) tools include large databases on the inputs and outputs for various production processes. For most of the base materials, the LCA data include the impacts caused by the transportation of all raw materials. For example, in the case of steel, the raw materials are coal, iron ore and limestone. Therefore, from the database in this tool, we have subtracted data about the basic energy use for the transportation of the raw materials needed. The database also includes the main source of origin of these raw materials, and therefore the transportation distance is known. Together these data give insight in the need for energy for the transportation of the raw materials. For our current analysis, we have not included any other effects, like shift of origin of the raw materials and improvements in energy efficiency of transportation nodes.

Passenger transport

For passenger transportation, two sets of vehicles were defined that can be used for VLEEM and link up with the methodology for energy efficiency improvements. A distinction is made between a standard development of energy efficiency in vehicles, and a more efficient development. Furthermore, different car fleets can be selected, based on preferences for the type of engine and/or the type of fuel. In Table 6, an overview is given on the energetic performances of these vehicles.

Table 6: Energetic performance of cars

CONVENTIONAL EFF IMPR

ENGINE	FUEL	ENERGY USE MJ/veh.km	TYPE of FUEL
ICE	Conv	1,74	oil
ICE	biofuel	1,74	MeOH
FCV	H2	1,30	H2
FCV	biofuel	1,39	MeOH
HYB	Conv	1,48	oil
HYB	biofuel	1,48	MeOH

ADVANCED EFF IMPROVEMENT

ENGINE	FUEL		
ICE	conv	0,98	oil
ICE	biofuel	0,98	MeOH
FCV	H2	0,73	H2
FCV	biofuel	0,78	MeOH
HYB	conv	0,83	oil
HYB	biofuel	0,83	MeOH

2.3.3 Buildings

Research on the housing sector is not yet completed. We will follow the approach as we suggest below.
The direct energy requirement for buildings can roughly be split up into three categories which cross the energy services delivered by BASES: electricity for appliances, energy for space heating and cooling, and hot water demand. Of these categories, especially the energy demand for space heating and cooling depends on the amount of floor space of the average dwelling. Following the same approach as in the materials sector we relate the per capita floor space to the per capita income and link this information to the amount of energy to ensure a comfortable room temperature (either through heating or cooling or both, depending on average climate information for the various regions).
From historical developments on the use of energy for space heating, large differences between countries are observed. Also, a trend towards more energy efficient space heating over this period for the countries that have an initially high energy demand for space heating can be observed, as shown in Figure 4.1
For a complete analysis of the energy demand of the future house, results from the monograph on the 'House of the Future' from the first phase of VLEEM, will be combined with this approach [Reisinger et al., 2002].

For the analysis on the amount of floor space, the relationship between per capita floor space versus per capita income, together with the number of households and average number of persons per household (which will both be available from the VLEEM-BASES model later on) we can derive an absolute number of square meters of floor space which is used to estimate the energy use in buildings.

From the DACES database, a first indication can be given for the amount of energy required for the heating requirements of dwellings. This data is available in different sets of energy efficiency improvements in the future. The data is listed in Table 7.

Table 7: Direct energy requirements for dwellings

Energy service	Best practice 1999	Dwelling type A	Dwelling type B	Dwelling type C	Unit
Space heating	80	67	37	20	MJ/m^2.a
Cooling	7	7	13	13	MJ/m^2.a
Water heating	4	3	2	1	GJ/a
Appliances	1920	1015	800	580	kWh/a

For a typical house of 120 m^2, this results in an energy demand for heating (room heating and warm water) of 3300 kWh, 2200 kWh and 1400 kWh for the A, B and C types, respectively.

The total energy demand is then 4300, 3000 and 2000 kWh, respectively. This is a factor 2 to 4 in terms of reduction of the energy demand compared to 2000 levels.

2.4 VLEEM software tools for supply technologies and software integration (tasks 4.2, 4.3, 4.4, 4.6)

2.4.1 The overall concept (tasks 4.4, 4.6)

The overall concept is sketched in figure 2. The software integration will be performed by an Geographical Information System (GIS) tool. This tool is used 1. to make a better geographical reference possible and to access the variety of information available in these formats 2. to have a common interface for all tools. The geographical reference is necessary for a couple of reasons: 1. description of the distribution of demand and resources 2. better representation of transportation infrastructure.

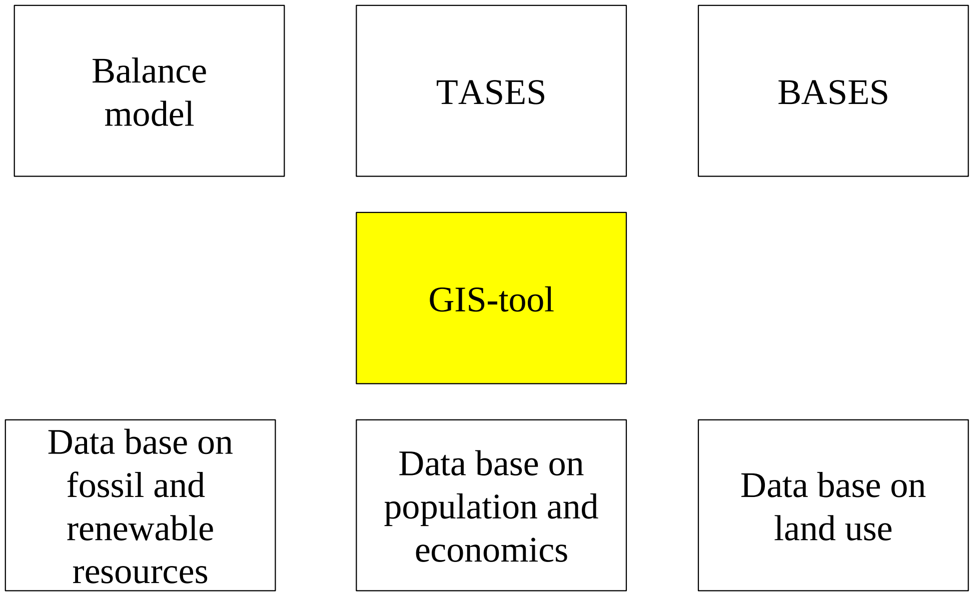


Figure 2: Overall organisation of the VLEEM software tools.

2.4.2 Balances (task 4.3)

The overall development of the energy system will be described in a extended energy balance table. A table will be designed for each world region and for selected milestone years and for the end-point year. All tables will be linked by certain restrictions, especially regarding the dynamics of the development and the use of scarce resources. The central goal of this software tool is to guarantee that the development is consistent, that the book-keeping is done correctly. The “real” dynamics will be controlled from outside and will not be implemented into the model.

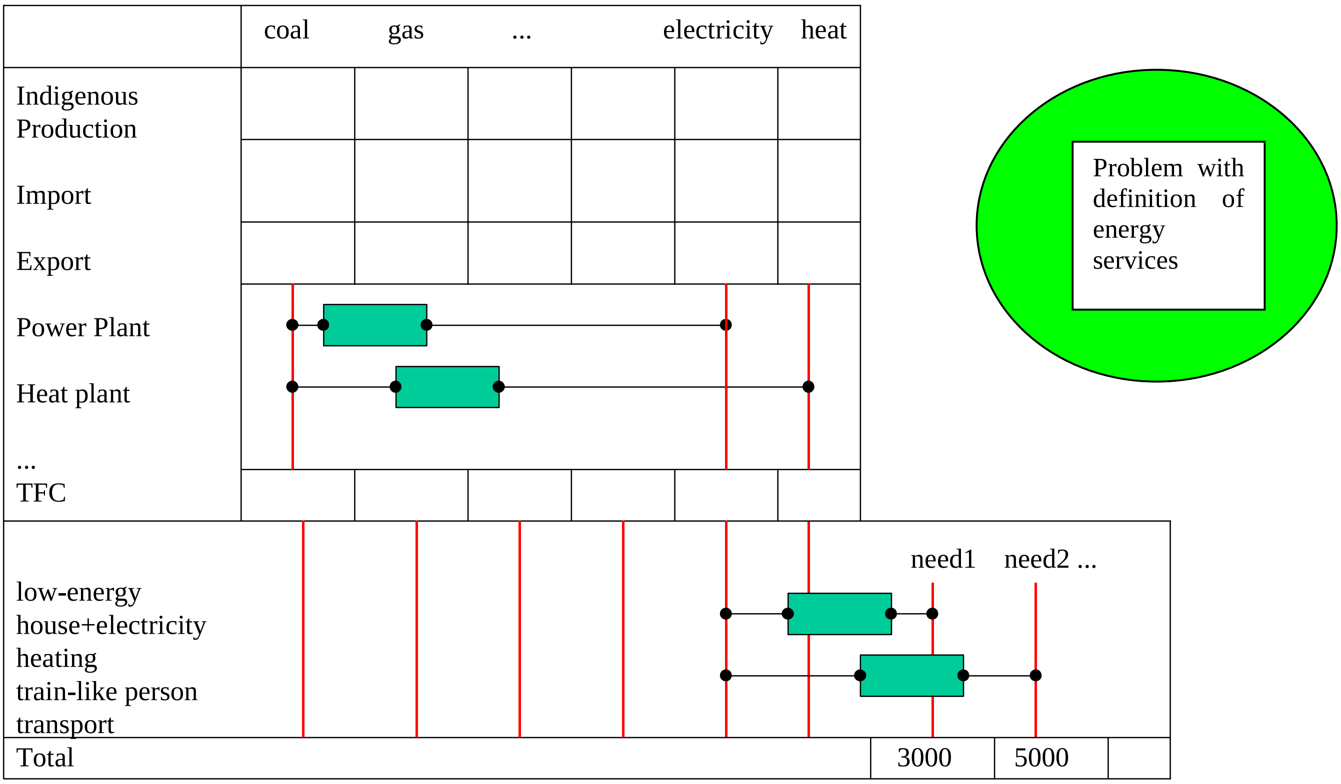


Figure 3: A sketch of the balance tables, which will be used in VLEEM for the back-casting analysis.

Figure 3 sketches the principles of the balance model. The balance model will be implemented in GAMS and a simple "optimisation" process will be performed. Again this optimisation will be controlled from outside and will only be done to understand the unavoidable dynamics which is mainly controlled by the ageing of old installations and diffusion of new technologies, environmental restrictions and resource availability. The model itself will be described more in detail elsewhere.

2.4.3 TASES (task 4.2)

The TASES tool will complement the analysis done with the balance table. While in the balance table a very rude spatial and temporal resolution is chosen, TASES offers a much more detailed analysis in this respect. TASES is actually based on two different modules: a simulation tool and a linear optimisation tool. TASES will be used to show the feasibility of different approaches and will be used to illustrate the necessary transport infra-structures.
In principle TASES offers the opportunity to go down in detail of the description level to power plants and high voltage power lines or refineries and major pipelines. Still it is still not meant to replace detailed engineering models, which will be still necessary to address some of the questions later on in the analysis. More details about TASES can be found in VLEEM I and (Biberacher, 2004).

2.4.4 Nuclear cycle modelling (task 4.2)

In order to facilitate the computation of nuclear mass flows, storage contents and waste amounts of nuclear expansion strategies in VLEEM 2 a PC-based Nuclear Mass Balance Model (NMBM) has been developed and tested. The code of NMBM has been written in

Microsoft Visual C++ 6.0, but the NMBM runs are executed via exe-files (and some Excel-files) which do not need the implementation of C++ at the user´s PC. The user would need C++ only if he/she would like to read the source codes or to change them.

The model consists logically of 3 parts:

- The capacity programme
- The mass balance programme
- A programme to perform computations with deliberately small time steps based on the results of (more or less) coarse time steps of a size of (normally) some years, e.g., 5 or 10 years within a time horizon of some decades, say a 100 years.
  This 3rd module is mainly of interest,
  1. if the model is part of a comprehensive (superior) energy model with nuclear contributions, and
  2. if this energy model simulates the operation of a plant park in small time steps (months, weeks, days or less).

The NMBM comprises therefore 3 time loops:

1. In the first loop the "coarse" time sequence of individual reactor capacities are calculated via the assumptions of individual capacity additions.
2. In the second loop the corresponding mass balances are calculated, considering operating capacities, capacity additions and retirements.
3. In the third loop the mass balances are calculated with deliberately small (constant) time steps and deliberately chosen load factors for each reactor type and time step (independent from the load factors in the "coarse" calculation where these factors are only reactor-dependent, not variable with time), but based on the dynamic reactor pool as defined for the "coarse" time steps (first and second loops).

More detailed information material on the NMBM is available in annex 6.

2.4.5 Data-basis (task 4.3)

Different data basis will be utilised or designed for VLEEM. A data base to describe the natural energy flows is under development utilising various sources. Description of fossil resources are under preparation.

(Biberacher, 2004) M. Biberacher, Methods for space and time resolved modelling of future energy systems, Ph. D. Thesis, Augsburg, 2004 (in preparation)

3 – Preparation of case studies (WP5)

3.1 Scenario storylines

3.1.1 Introduction

Based on VLEEM's synthesis "Accounting for Sustainability in VLEEM", 3 population development scenarios are further elaborated hereafter. They aim at describing consistent demographic and socio-economic environment in which environmentally sustainable energy systems can be assessed. The main discriminating factors among these scenarios are mostly cultural and social

The scenarios are :

1. **HiPop** with high demography in 2100 with near 12 billion people, corresponds to a very slow demographic transition process towards a low fertility rate in developing countries where religious and cultural determinism remain very strong and change only very slowly: south Asia, conservative Muslim countries, sub-Saharan Africa. It corresponds also to a relative success of nativity policies in the industrialised countries where the demographic transition is now completed.

2. **MidPop** as 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 parts of the world by 2050, and that governments succeed in convincing educated women to get slightly more than two children in their life. This scenario also means that the transition to universal education and democracy has also been achieved everywhere, and that collective values, inspired by regional value systems, are stronger than the development of individualism.

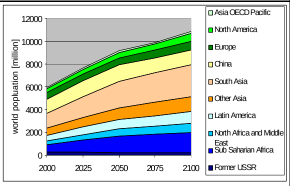
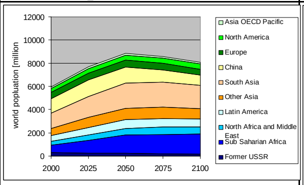
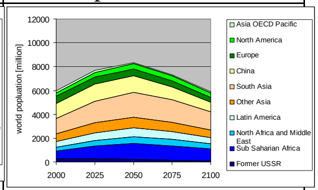
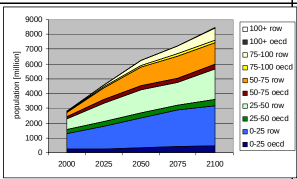
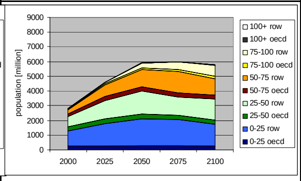
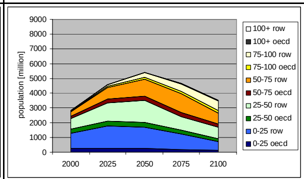
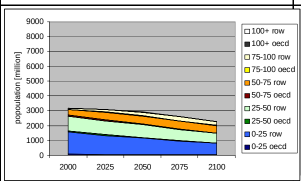
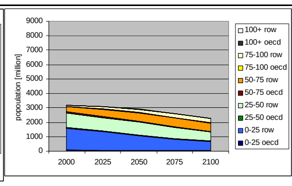
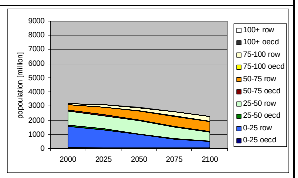
3. **LowPop** storyline with little growth, same or less population than today (+/- 6 billion). The demographic transition will be completed by 2050, with a peak population around 8 billions at that time. After that, the trend towards a decreasing fertility rate continues in developing countries, and nativity policies, if any, fail to convince women to get more children almost everywhere. This scenario means that individual values take the lead over collective values.

In order to describe the content and logic of these three scenarios, available material and elements from Shell ("People and connections, global scenarios to 2020") and IPCC (SRES) have been used whenever relevant. At this moment it is a rather qualitative description, specific parameters are still open for discussion. A next phase will be the quantification of these selected parameters.

In all scenarios, we consider that the depopulation of rural areas and the growth of urbanised areas continue and do cause shifts in life style and cultural patterns. Access to "modern" infrastructure and communication technologies facilitates access to minds of people and creates technological frog-leaps (e.g. like cell phones in the developing world nowadays) on the one hand, but do also create at the same time a global and levelling view on cultural and social values (TV, internet, …., "hamburger and cola culture") and an extremisation of cultural and traditional identities. NVevertheless, the magnitude and the speed of these phenomena are different in the three scenarios, according to the weight of cultural and religious traditions behind demographic assumptions.

The construction of these scenarios is mostly based on an analysis of the causal relations between the forces behind the demographic development and their social, economical and geographical consequences, without value judgement on these consequences (as far as possible…).

3.1.2 Scenarios description

	HiPop	MidPop	LowPop
total population by region			
age structure urban population			
age structure rural population			
Life-styles, social link	Convergence of life styles of the “elites” of the production system throughout the industrialised and industrialising world (US model?); Growing economic discrepancies between these people and the common people everywhere; growing weakness of the social link and growing social unrest. The traditional life styles give up only very slowly in the developing world; social problems are solved through emigration.	Strengthening of specific regional modern life styles, according to regional “elites” life styles. The regional elites profit from an increased communication and global availability of novelties, services and goods. Social discrepancies are mostly solved through transfer and redistribution mechanisms, both within region as interregional. The lower population growth, especially in the industrialised world and Asia, and aging effects cause a larger share of	Convergence of life styles of the “elites” of the production system throughout the whole world up to 2050. Growing economic discrepancies between these people and the common people everywhere; growing weakness of the social link and growing social unrest. After 2050, regional adaptation to the regional problems resulting from the general population decline and aging (15 36% in the developed world; 7 33% for the developing world). This scenarios has the largest

	The share of aged people (65+) is growing significantly (9% 21%), especially in the developing world (tripling by 2100, 7% 20% and even 22% in rural areas), creating a global need for extensive health services and facilities, growing urbanisation and concentration makes them however more efficient and accessible.	elderly person in the population (9 26%), however the share of 20-65 years olds remain more or less constant (47-50%).	share of elderly people, but at the same time a somewhat higher share of potential economic active persons. This unbalance creates the most heavy burden on public funds to secure adequate health services.
Potential economic development	**Industrialised and industrialising countries**: high population results in high active population, i.e. high potential labour. High and homogenous education in each region results in a high information level and high labour productivity; retirement and working hours strongly influenced by "struggle for job (life)" **Developing countries** : major cultural and religious resistance to education and labour of women; the active population do not rise as fast as total population; average and education information level and labour productivity rise slowly; both put a high burden on the potential economic development, together with a vast and fast growing number of elderly people who do not participate in economic life themselves but on a positive side who are responsible for a parallel growth of the service sectors. Depopulation (urban pull) and aging in rural areas causes abandonment and less	Active population development only constrained by demography; education and information level progress well everywhere and quality converges to a high global level; retirement and working hours reflecting cultural values specific to each region. The aging and population decline puts a heavy burden on public funds, nevertheless private initiatives to support pension and health service flourish, allowing governments to use revenues for other purposes, like R&D or education.	Active population development only constrained by demography; education and information level progress well everywhere up to 2050. Retirement and working hours strongly influenced by "struggle for life" everywhere after 2050, the social system becomes very hard to maintain if the same labour conditions as in the HighPop or Midpop scenarios, a longer working life time (65 70) is very probably.

	care taking for elderly people and a welfare loss. Public budgets and pension funds are heavily under pressure because of the unequal participation in labour by women and the growing amount of pensioners.		
Actual economic development	**Industrialised and industrializing countries**: - no particular constraints on investment side, neither economic nor financial - possible social unrest due to high growing inequalities between the available career/job opportunities for business class and for common people. **Developing countries**: - possible financial constraint on investments due to unstable political situation and high risk for foreign investors; - economic unbalances due to high population	**All**: - no particular constraint from the investment side, neither economic nor financial - social and political climate favourable for foreign investors in all regions without severe barriers. **Industrialising, developing countries**: time needed to build up the necessary infrastructures; investment trade-off infrastructures-production.	**All, up to 2050**: no particular constraint from the investment side, neither economic nor financial political climate favourable for foreign investors in all regions, although social unrest may be a handicap. **Industrialising, developing countries**: time needed to build up the necessary infrastructures; trade-off infrastructures-production in investment **All, after 2050**: Increasing economic and financial burden resulting from aging population and leading to more and more severe economic unbalances
Capital flows	Deruralisation and the fact that active population shares do shift only a couple of percent points create : * a potentially large capital availability in the developed world, which is however used to satisfy the increased service needs and not so much as innovative capital for the industry; * in the developing world most of the capital is generated in urban areas where it is used in the intensive and concentrated needs (infrastructure (industry) and service).	The share of potential economic active people is somewhat higher than in HighPop, generating a higher cash flow and creating a higher and more balanced welfare level. The depopulation of rural areas however continues, higher in the developed world (halfs) than in the developing world (-1/4). The fact that the developed world's population deceases more is however a brake on a continuous high development, the developing world can take over partially the economic drive.	As Midpop to 2050, afterwards, welfare decreases due to the aging and declining population. Capital flow or savings are very low, emphasis is given to securing (health and social) services dealing with the population mix.

Migration pattern	**Economic Pull**: - within industrialised and industrialising world, discrepancies in affluence increase, calling for increased migration movement - from developing to industrialised and industrialising world, attraction of high education people by high salaries -within developing world incentives to migrations **Social/political push:** - within industrialised and industrialising world, few pressure to migrate - from developing to industrialised and industrialising world, and within the developing world, social/political pressure force people to migrate, but not highly educated immigrants are not welcome	**Economic Pull:** -substantial improvement of living conditions everywhere progressively decrease the search for “eldorados” **Social/political push:** - more quiet world, less social/political pressure forcing people to migrate	**Economic Pull:** -substantial improvement of living conditions everywhere progressively decrease the search for “eldorados” up to 2050; afterwards economic conditions deteriorate unequally throughout the world, creating new migration movements **Social/political push:** - more quiet world, less social/political pressure forcing people to migrate - active immigrants are more and more welcome as population is aging
Land use changes - agricultural policies	With substantial food requirements for the continuous population growth, there is large pressure and demand for ongoing R&D and innovation in agricultural techniques in order keeping on improving production efficiency and food quality; the developed world experiences an increasing urbanisation putting more pressure on land area for other uses (mobility, recreation, nature) and at the same time is concerned about environmental impacts (high pressure leads to unwanted and damaging effects); the developing world has less interest in	The initial population growth pattern, equal to HighPop, and the slow starting shift from rural to urbanised areas, requires a very efficient food system. Agriculture is highly intensived, mechanised and technologised everywhere, resulting in higher efficiencies in production and less sweet water needs. The lower population growth in the second half of the century, puts less pressure on land and all activities related to land use get balanced.	Trends are similar to mid-pop until 2050. The declining population after 2050 can satisfactory depend on the already occurred changes and let more space available for other end-uses of land.

	conserving the environment because pressure for food is overwhelming and improvement in agricultural techniques is slow; also a high number of large metropolises emerge, and degradation of rural land continues with decreasing yields. Scarcity in sweet water increases dramatically in the developing world, due to increasing needs and bad management techniques		
Resource availability	**industrialised/industrialising regions:** the drive from the developed world to fuel its economy results in successful resource development, both conventional (ultra deep sea oil and gas , …) as unconventional (nuclear, fusion, renewables) . **developing regions** the resistance and risks for foreign investment slows down the process of resources development ; the developing world remains mainly with its domestic ready available resources and hardly profits from the new resources' development.	**high** the progressive disappearance of barriers to trade and financial flows among regions allows for a rapid expansion of existing resources all over the world, allowing access for all at market prices. Further development and exploitation of resources is mainly market driven and international ventures ensure the necessary infrastructure investments.	**high** same as in mid-pop
Resource distribution	Security of supply is a master word in the **industrialised/industrialising regions**; this means supply diversification strategies (origins and fuels) and limited endogenous production; **Developing countries** have a restrictive export policy of natural resources, for cultural/political reasons mainly	Resources become a globalised market good, owned by private companies which have a wide portfolio of possibilities to offer on the market; it remains a "demand" market, with probably some commodity price level setting by the authorities in order to equalise energy cost over the consumers.	same as in mid-pop
Transfer and	The demand for tailor	In order to minimise risk	The high rise in the first

deployment of technologies	made products and services is high, including cheap standard of-the shelf solutions at low cost as well as very specialised ones, which are tailored to the needs of small groups of customers who are willing to pay more for a guaranteed service. The "mass market" solutions are abundantly available at low costs, especially in urbanised areas (global) and certainly in the developed world. Strong competition between providers may keep prices down. Historic dynamics do continue in technology change. Manufacturing is built upon regional resources and needs, leading to a high variation on the supply side. The danger from technologies as perceived by the public is not the same as the actual danger. this puts a high pressure on technologies which bear the risk of major disasters (e.g. nuclear, large infrastructures (pipelines, tankers)).	for the environment (and to be able to react reasonably quickly to new findings and developments), there are no big monoculture of technologies, diversification is the main policy of companies. In transition periods, technologies and energy carriers which may not be strictly renewable or environmental neutral, but with a low impact on the environment, appear. Demand and supply are well balanced and access to technology is easy and widespread, but technologies with negative environmental effects have little market potential.	half drives technology development and transfer, large monotechnologies appear at low cost availability. Innovation is rather limited, performance and efficiency are the key topics. The population drive does contribute to continuous technology development, but once the trend has turned, further development slows down and only very specific regional applications for local needs emerge.

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- 3.2 Case studies outlines
  - ⇒ Energy efficiency options
  - ⇒ Technology cluster versus networks
  - ⇒ High renewables
  - ⇒ High nuclear
  - ⇒ High fossil / CO2 savings

3.2 VLEEM II cases studies on environmentally sustainable energy systems

3.2.1 Introduction

The case studies that will be analysed in VLEEM II are discussed and motivated hereafter. Each case study is designed around certain technological clusters. The analysis should discuss the feasibility of the cluster to supply considerable fractions of the global energy system and should illustrate possible impacts on society, environment and economy, in particular as regards the demographic scenarios. The first grouping of clusters will follow the primary energy carriers – this is certainly a more traditional approach and puts a too strong emphasise on the supply side. The next grouping will go along the energy carriers reaching the final consumer, a more in-depth analysis of the possible competition between hydrogen and electricity will be presented. The last analysis will start from the possible restructuring of the final energy demand, how could very efficient housing or transport technologies be implemented.

3.2.2 Cases around primary energy carriers

Fossil fuels

On the long run fossil fuels can only support a sustainable energy future, if unconventional fossil fuel resources like gas hydrates or coal are utilised on a large scale. So even in such a case the structure of the energy system will change. The analysis will again be divided in two cases: a case where gas hydrates dominate and a case where coal dominates – the later case might be restricted to certain world regions, like North America or Russia. In any case it is assumed that oil – including unconventional resources – will only play a marginal or at least declining role in the year 2100. Other studies come to similar results (see figure 4). This implies that especially new fuels for the transport sector need to be developed.

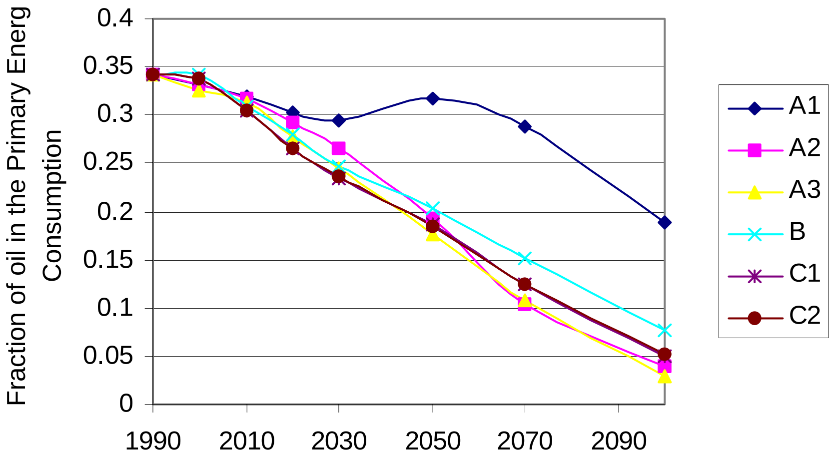

Figure 4: In the various scenarios (A1, A2, A3, B, C1,C2) of the IIASA/WEC study the importance of oil is declining.

It is again obvious that any serious CO2 reduction strategy can only be implemented if either CO2 is sequestered or the energy demand is reduced considerable. The case study has three major parts:

- identification of possible resources, discussion of techniques to “mine” these resources, in case of gas hydrates this is certainly an open question
- identification of suitable end-energy carriers and necessary infrastructures
- identification of CO2-stores and techniques to scrub the CO2 properly

As already mentioned in VLEEM I rather advanced concepts should be investigated.

High nuclear case

The conditions under which nuclear energy should be considered to be sustainable were already discussed elsewhere. Mainly two requirements are formulated: inherent safe nuclear reactors and strong reduction of the long-lived radioactive waste. The current energy system is usually considered as oil age. Oil covers roughly 35 % of the primary energy consumption. In the future it is generally expected that the number of primary energy sources will increase, while the role of each individual source will decrease. In former studies like the IIASA/WEC study nuclear played a dominant role in the year 2100. At the end of the 21st century (see figure 5) 24 % of or 8.3 Gtoe of primary energy consumption were covered by nuclear.

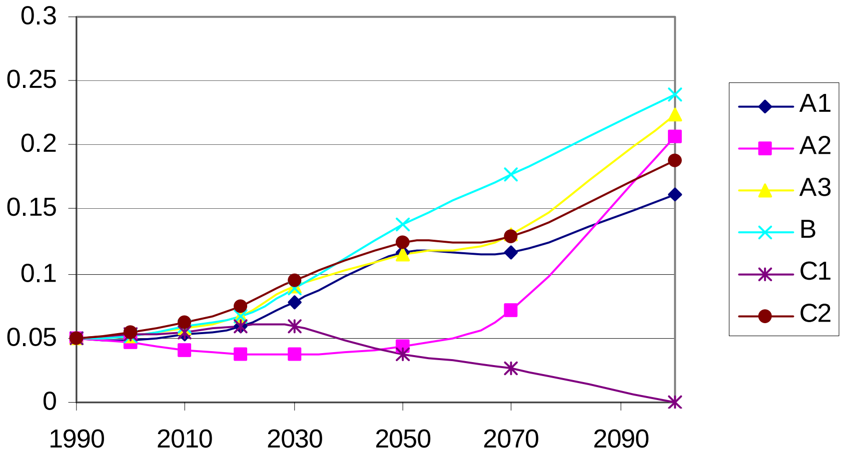

Figure 5: Fraction of the primary energy supplied by nuclear power in the different IIASA/WEC scenarios.

Although the primary energy is not dominated by nuclear power, it plays with the exception of the C1 scenario a quite substantial role.

The VLEEM cases, in which also nuclear fusion will be considered as option form 2050 on, will – as mentioned already – investigate the following items:

- resource situation
- technological implication of the sustainability criteria, R&D requirements
- organisation and geographical distribution of the complete fuel cycle
- production of secondary energy carriers beside electricity

The case will be first elaborated for a small region like Bavaria. In this region nearly 100 % of the energy services will be covered by nuclear. This is then expanded to a complete world region, certainly keeping the total fraction of nuclear always below 50 % of the total primary energy consumption. At the end an estimate of the "leakage" rate of radioisotopes into the atmosphere will be done and the question will be addressed, which "leakage" rate might be acceptable.

High renewable case

The renewable cases will be mainly grouped around the following questions:

- which fraction of the natural energy flows can really be harvested
- which effort has to be taken to smooth annual, seasonal or hourly variations
- the natural energy flows differ considerable between various world regions, how will this disparity influence the development

Three major pictures will be developed:

- solar/wind/hydro global link
- high diverse regional renewable energy system, "all" options are utilised
- intense use of biomass

A global link of the best wind, solar and hydro sites via an huge electricity network might be the result of intense co-operation world wide, a prosperous economic development and an considerable increase in energy demand. More regional solutions seem feasible, if really a large fraction of the possible energy flows are harvested and if measures of rational energy use can be installed. The biomass picture is especially tempting. Biomass can practically be converted to any of the required energy carriers, but the supply is limited. In a low population world with high agricultural standard the intense use of biomass seems feasible.

3.2.3 Hydrogen versus electricity, diversity in energy carriers, competition or necessary supplement

The demand for clean and easy to handle energy carriers increased in the 20th century and lead to an steady increase in electricity demand and the replacement of coal by oil and then a replacement of oil by gas in the heating sector. This trend is expected to continue. It leaves the question open if electricity, gas/hydrogen or methanol or something completely new will be the winner in this race or if a well balanced mix between these energy carriers will be realised. Special applications in industry will always require some special solutions. Figure 6 shows the development of the final energy carriers as projected in the IIASA/WEC scenarios. Here a mix is realised although electricity plays the most important role in 2100.

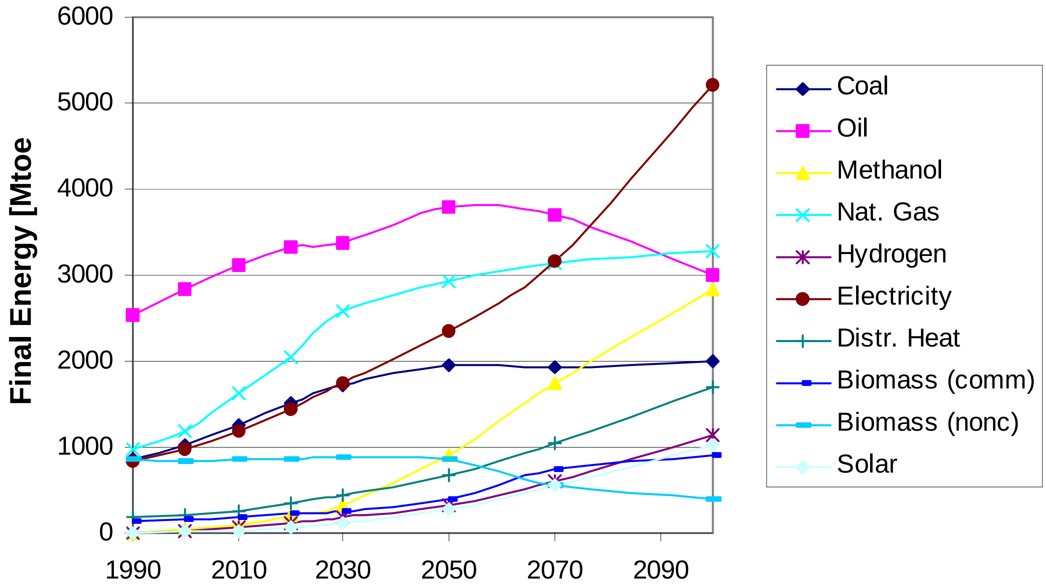

Figure 6: Distribution of final energy carriers in the IIASA/WEC study.

The case study should start to discuss in more detail possible applications of hydrogen:

- how would a "typical" settlement look like which is supplied by hydrogen only, would hydrogen "penetrate" deep into the buildings and fuel cells would replace power supplies (Ruhrgas vision)
- how would an energy intensive company be organised, do we expect legions of fuel cells or one central and very refined heat distribution and so on (here it might be wise to look back into the early days of electrification, companies replaced at first only the steam engine with

an electric motor and kept the sometimes rather complex structures of traction belts, it took a while until the motors became smaller and were applied directly, in case of fuel cells at lest for traction the electrical motor will remain)

- how would a gasoline station look like, the distribution system, could it be connected to the other “hydrogen” net, would gasoline station function as distribution systems, what are expected pressure levels
- hydrogen supply of a future airport

These options should of course always be discussed in contrast to alternative supply options (electricity, methanol, ...). In a next step hydrogen sources should be discussed. The information of the case studies mentioned above should be utilised here. This analysis will include the following items:

- central versus de-central hydrogen production, e.g. could gasoline stations be organised as decentralised hydrogen production
- hydrogen from fossil fuels, hydrogen from nuclear, hydrogen from renewable energy sources

and then later on the complete infrastructure:

- possible storage option in geological formations, in technical devices, what are the limits,
- trading options, pipeline and tankers

The analysis should focus on crucial decisions in this respect.

3.2.4 Dealing with energy efficiency in the case studies

This case should focus on energy systems which have a considerable lower primary energy demand, although they offer in principle the same energy services. It is certainly a delicate problem to decide which energy services are equivalent. From a very abstract point of view it might make no difference, if we travel in a noise packed bus or in luxury car, but in practical terms this difference counts and does lead to rather different consumer decisions.

In certain technological paradigms, energy efficiency improvements are expected to be more substantial than in others. This is represented by the lower curve in the graphs on future development of the specific energy consumption (SEC): While in the standard case one third of the gap between the projected energy use by 2050 and the thermodynamic minimum is bridged, another $1/3^{rd}$ of the remaining gap between the energy consumption in 2050 and the thermodynamic minimum is reduced in the period 2050-2100 in the high energy efficiency case. For each technological paradigm, arguments have to be given why a choice for either the standard development, or the more efficient development has been made. In this document, we would like to give a first indication on the possible arguments for these choices. In these discussions, the standard efficiency development will be referred to as ‘A’, while the more efficient development will be referred to as ‘B’.

High Renewables Case

In general a high share of renewable energies may be assumed to lead to higher energy prices. The correctness of such a statement depends on many factors, among them
the technological progress in renewables (especially for photovolatics),
the degree to which new renewable energies will be implemented with a strategy to "buy down" the costs
and the price development for the conventional fuels which, in turn, depend on numerous issues such as global political stability, the point of time when the depletion mid point will be reached, and the pace of industrialization and change of lifestyle in the developing world.

On the other hand it has been argued that initially higher costs for renewables in the initial stage will more than pay off in the long term, with important reasons being technological learning, economies of scale, lower dependency of imports from abroad and lower externalities. While there are good reasons to follow this line of reasoning arguments, one may also ask the question *when* the breakeven point will be reached and to which extent its position will determine the production and consumption patterns in general.

In VLEEM, we do not make a statement about the year when the breakeven point will be reached but we do expect that the multiple breakthroughs required in the various technologies will not be realized very easily. Higher cost in an initial stage (which could take some decades) is therefore assumed to lead to increased energy efficiency in industry, commerce and in private consumption which would not necessarily occur otherwise. In private transportation, for example, the hybrid car and the fuel cell vehicle are assumed to replace rather quickly cars with internal combustion engines (DACES, 2001). In general, the High Renewables case is therefore equated to the B development, even though energy efficiency could gradually loose impetus in later decades.

A special situation may arise for the chemical industry where fossil fuels are used as feedstocks. The increased use of renewables in general may mean that there will be less environmental pressure and little benefits in financial terms, and therefore industry can continue to use fossil fuels for feedstock purposes (oil for the production of polymers, coal for the production of steel, and so on). If that is the case, it can be assumed that the development for these (*) industry sectors can follow a 'A' development, because there are no drastic changes in production routes.

On the other hand, a high renewable case can also imply that only bio-based feedstock should be used. In that case, the assumed price for these bio-feedstocks can make the difference between a choice for 'A' or 'B'. When prices are high, the chemical industry is less likely to replace conventional feedstocks by renewable feedstocks
For the petrochemical industry, the use of bio-based feedstocks will result in an additional step that will be needed for the production of petrochemicals. This will most likely result in a standard development, with no space for additional efficiency improvements.

High Nuclear Case

Similar to renewables, the success or failure of nuclear energy on a worldwide basis will depend upon numerous factors, among them
breakthrough of fusion

public acceptance, linked to whether or not inherently safe reactors will be commercialized
climate change

If nuclear energy turns out to be very successful, large amounts of hydrogen could become available available. In industry, this could be used in several sectors. For some processes, hydrogen serves as a feedstock or reducing agent. For iron and steel, there is no indication that a direct reduction route using hydrogen as the reducing agent instead of cokes, has an advantage (in terms of energy use) above the current coal-dominated route. In the case of ammonia production, the availability of hydrogen would imply that there is no need for a steam reformer to operate at the ammonia plant to create hydrogen from natural gas as a feedstock for ammonia production. This can increase the efficiency for ammonia production. In general though, for industry (and commerce), we conclude that in this case, an ‘A’ development is more likely to occur than a ‘B’ development.

For transportation, the use of FCV will be dominant when large quantities of hydrogen are available. These vehicles usually have a higher efficiency than ICE based vehicles, and this would therefore imply a ‘B’ development (more efficient).

When in a high nuclear case the success of nuclear energy is not that large, then it is likely for electricity prices to remain rather high, and little capacity will be available for hydrogen production. It is then likely that all electricity consuming sectors will increase energy efficiency to high levels, due to the high(er) costs for electricity and thus follow an ‘B’ development.
For especially the transport sector, where hydrogen will not be available at low prices, and therefore other energy carriers OR expensive hydrogen is needed, the trend that will be followed is more likely to be less efficient, so ‘B’.

High Fossil Case

In a High Fossil Case, the bulk of the CO_2 emissions of point sources will be captured and stored. For diffuse sources, mainly the transportation sector, this will not be possible, unless the fuel is decarbonized before it is distributed. That implies a hydrogen fuelled transportation system, for which the same argument will be valid as in the high nuclear case. If this is not the case, than a high efficiency development will still be likely, since in a high fossil case, emissions should be kept as low as possible, either through CO_2 sequestration or high increases in energy efficiency.

For industry that relies on fossil carbon sources as feedstock, investments have to be made for CO_2 sequestration units, and additional investments for more energy efficient technologies will therefore not likely be made. Sequestration will also cost some energy (especially if transportation to sequestration locations becomes necessary). Therefore, a standard development ‘A’, is more likely to occur.

ANNEXES

ANNEX 1 Accounting for sustainability in VLEEM: a synthesis
ANNEX 2 Prospective sur les budgets temps ; éléments de réflexion pour le modèle VLEEM
ANNEX 3 Modelling impacts of demographic evolution on macro-economics: formula and preliminary results
ANNEX 4 La dynamique du temps de loisir
ANNEX 5 Demand for Energy Carriers – DACES
ANNEX 6 Nuclear cycle modelling in VLEEM
ANNEX 7 Monograph on hydropower