Energy Scenarios For A Sustainable Future

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Abstract ***– It is clear that the future is not simply something already predetermined that we must accept blindly: rather, it is open and to a large extent determined by the course of actions we decide to take. For this reason, we need to look at the future and its uncertainties in an articulated fashion, developing specific tools to consider both how the future might unfold if we do not act and how we might like the future to unfold if action were to be taken.***

As demonstrated on valuable intellectual exercise for looking into an uncertain future involves the development of "scenarios" intended as logical and plausible conjectures about how fundamental drivers will affect global societies, economics, resource use and the environment. The literature review shows a multiplicity of scenarios, conducted as different scales ranging from the national to the global scale, with different time horizons and with a focus on different strategic issues.

Exploratory scenarios help prepare for events that, without representing a straight-line continuation of past trends, are plausible and entirely possible. Exploratory scenarios can help a lot to accelerate and calibrate the response to new developments, as well as providing a strategic framework technology development policy.

Normative scenario has, as its goal, the evolution of a desirable future rather than a future inexorably imposed upon us by the inertia of system. Building a normative scenario requires the creators to clearly define the desirable characteristics of their future, and to express this future in terms of measurable targets.

The use of such a scenario process lies as much in the issues it requires us to comfort as the precise details is generates. The future will not look exactly like the one envisioned: other priorities will intercede and national conditions and circumstances will dictate the specifics of the energy policies that may be adopted. But such a process of interacting around scenarios can provide valuable guidance as to what we must do – collectively and individually – to achieve the set policy goals.

I. FOREWORD

Analyzing the intersection between energy and issues of climate change mitigation requires the adoption of a long-term perspective.

These facts lead to two important considerations:

- over the long term a through understanding of the main elements of uncertainty is the base for any strategic planning.
- over the longer term an additional element of freedom comes into play inasmuch as the future can be shaped by political will.

While it is clear that scenario work at the scale needed to analyze global energy and environment futures is likely to require time and intellectual resources, we should not be satisfied with producing and using only one type of scenario. What are scenarios and why they are useful?

II. DIFFERENT TYPES OF SCENARIO

The type of scenario with which we are most familiar is the reference scenario of the forecasting type, which assumes the continuation of historical trends into the future and that the structure of the system remains unchanged or responds in predetermined forms.

Exploratory scenarios thus can:

- help scientists and policy analysts to identify main dimensions and drives that shape those future world.
- help them to explore and understand the dynamic links among the main drivers and to assess their relative importance (in terms of potential impacts) as sources of uncertainty.
- allow a more systematic and full appreciation of the uncertainties that lie ahead in the energy and environment domain.

That is to say such scenarios assume that policy actions can shape or future in the desired image and they are designed to identify the policy actions required.

The objectives pursued are manifold:

- to strengthen the analysis of energy and environment issues over the long term by aiding in the correct identification of the main drivers of the change and in understanding the dynamic links among these drivers;
- to clarify the relationship between short-term and longer-term objectives, and how they change over time under the pressure of long term and factors;
- ·to ensure greater consistency between long-term policy objectives and policies to bring them about, particularly with respect to the planning of the policies and their impact over time.

A systematic characterization of the scenarios examined in the literature is provided together with a critique, to arrive at the identification of gaps and areas that need further work.

As a result three different images of the world are given and, consistent with those images of the world are suggested for the energy technologies that are likely to emerge in each of those worlds. The conclusions and implications, including in the domains of policy analysis and strategic planning, are as well as an implication for further analysis.

III. BASIC DEFINITIONS

Scenarios are a tool for helping us to take a long view in a world of great uncertainty. The name comes from theatrical term "scenario" – the script for a film or play. Scenarios are stories about the way the world might term out, tomorrow, stories that can help us recognize and adopt to changing aspects of present environment.

In this context, the precise definition of "scenario" is "a tool for ordering one's perceptions about alternative future environment in which one's decision might be played out.

Alternatively: a set of organized ways for us to dream effectively about stories, either written out or often spoken. However, these stories are built around carefully constructed "plots" that make the significant elements of the world scene stand out boldly. Thus approach is more a disciplined way of thinking than a formal methodology.

"Many have tried to understand the future purely through prediction, even though the record to date is poor. Forecasters extrapolate from the past, imposing the patterns they see in the past onto the future, and tend to neglect the oft quoted statement that a trend is a trend until it bends. And it is the bends that are generally of most interest to us because it is the carry the most risk or offer the greatest opportunities.

The end result of a scenario exercise is not an accurate picture of tomorrow, but better decisions about the future.

A fundamental requirement of scenarios is that they be internally consistent logical and plausible constructs of how the future might unfold. Furthermore scenario building is an inherently interdisciplinary process, because it needs to take into account the many dimensions of the same problem.

Scenarios need to integrate long-term phenomena (including demographic, technological or ecosystem trends) with shorten-term phenomena (like inflation or spikes in oil prices). Scenarios should also possess the capability of challenging users' mental maps, because that is when a true possibility to learn exists.

The process of scenario building is a complex analytical exercise. Five main steps are discernible:

a) define the problem and its horizon or isolate the decision that needs to be made;

b) gather information, expert opinion and build a coherent system that includes all relevant actors and agents, including the factors and links (both quantitative and qualitative) between term.

c) identify the key factors that would affect decisions and separate predetermined or unavoidable factors and trends from those that are highly uncertain or depend on will;

d) rank these factors by importance for the success of the focal issue (defined in step 1) or by uncertainty and identify the two or three factors or trends that are most important and most uncertain. These will represent the main axes along which scenarios will differ and will be characterized. Predetermined elements / factors will remain unchanged in all scenarios.

e) flesch out the scenarios in the form of consistent narratives or "stories".

The next logical step is to examine the implications of the various scenarios and translate them into clear strategic choices. Different choices can at that point be tested for robustness/resilience against the scenarios out lined.

The scenario process outlined above corresponds, strict by speaking, to that of so-called "exploratory" or "descriptive" scenarios, build for the purpose of exploring a range of outcomes and analyze their implication for strategic decision making.

IV. BASIC DEFINITIONS

Mathematical and statistical models can be used a tool in long-term scenario analysis. In following review, we shall focus on scenarios ande deal with models only when used to quantifity a specific scenario.

A. Shell's Scenarios

The main questions explored by the new Shell's scenarios resolve around these factors:

- how long will oil and gas resources be able to meet rising demand and what will replace oil in transport;
- what will drive market growth and cost reduction of renewable;
- what will a hydrogen infrastructure develop;
- what will social and personal priorities be, and how will they affect energy choices.

What energy needs, choices and possibilities will shape a global energy system which halts the rise in human induced carbon dioxin emission within the next 50 years – leading to stabilizing of atmospheric carbon levels below 550 ppmv – without jeopardizing economic development?

The two scenarios (called Dynamic as Usual and The Spirit of the Coming Age) suggest that by the middle of this century an affordable and sustainable energy system could indeed be emerging. They also show some common traits that should be carefully taken into account in outlining any sensible energy strategy.

- a role of natural gas as a bridge fuel over the next two decades and the importance of security in its supply:
- a strong volatility in oil markets;
- a shift towards distributed or decentralized head and power supply;
- the potential for renewable and the importance of energy storage technologies (both for power and hydrogen);
- the difficulty of identifying winning technologies in periods of high innovation and experimentation.

B. Global Scenario Group (GSG)

The team of experts and scientists involved in this work recognized manifold dimensions of globalization (geopolitical, cultural, technological, economic, biologic, climatic) and the fact that world system is at an uncertain branch point from which a wide range of possible futures could unfold in the 21st century.

The increasingly interdependent global system we observe today is a way station in this sweeping process of growth, transformation and expansion. But a new and ominous feature of the current phase of history is that human impacts and the environment have reached global scales. The contradiction between the growth imperative of the modern world system and the constraints of finite planet will be resolved. The critical question is how?

The drivers that shape the present situation are separated into two categories "proximate" drivers and "ultimate" drivers.

Ultimate drivers include: values, desires and aspirations; structure of power; knowledge and understanding; human needs; long-terms ecological processes.

Among proximate drives the Global Scenario Group includes: population size and growth; economic volume and patterns; technological choice; governance; environmental quality.

C. World Business Council for Sustainable Development

These scenarios are development:

- the FROG (First Raise Our Growth) scenario;
- the Geopolity scenario and
- Jazz scenario.

The scenario are development:

- what are the critical environmental theresholds and how resilient is the global ecosystem?
- what human social systems can best respond to the challenge of sustainable development?

Three keys driving forces are identified which can be considered as "predetermined" elements that will certainly persist into the future and shape all scenarios:

- social and technological innovations, new economic and social actors;
- population increase;
- increasing interdependence and interconnectedness, thanks to new communication technologies that increase the speed of knowledge transfer, but unfortunately do not yes raise the speed of problem solution, due to the growing complexity of governance.

D. Intergovernamental Panel on Climate Change Scenarios

The Climate Change Scenarios, exploring a temporal horizon that extends to 2100.

The process involved:

- an extensive review of the existing scenario literature;
- the analysis of the main scenario characteristics their different driving forces and their relationships;
- the formulation of four main storylines as narrative description of as many alternative futures;
- the quantification of the storylines through the use of a wide array of models and modeling approaches;
- the review of the resulting emissions scenarios and of their assumptions through and open consultation process;
- repeated revisions, following this review process.

The resulting set of 40 quantified scenarios converts a wide range of uncertainties on future emission deriving from:

- uncertainties in the parameters expressing the driving forces (demographic, social, economic and technological ones). It is interesting to note that 13 of these scenarios are devoted to the exploration of differences stemming from different energy technology assumptions.
- differences in models' characteristics and structure.

It is important to note that no probability of occurrence is assigned a priori to these scenarios.

E. Millennium Project

The process of developing the scenarios after a through literature survey, started with a questionnaire sent via e-mail a certain number of correspondents. The questionnaire presented a list of 18 fundamental drivers or dimensions that could be used to span the scenarios and asked participants to indicate the four most important. Among the 35 response to the questionnaire, the four highest raking drivers or dimensions were:

- degree of globalization (from free trade to isolationism);
- communications technology (from vibrant to stagnant);
- threats to global security and / or quality of life (high to low);
- government participation in society (high involvement to little, oh "laisez faire").

At the beginning of the project, an informal enquiry was conducted among selected global modelers, about models and their potential uses in scenarios.

Questions asked were:

- What models would you consider for this application?
- Specific scenarios and generalized models don't mach. Is it then necessary to build specialized models to quantify a specialized scenario?
- How can we effectively link specialized scenarios into more general global models?
- Do you know of any global models that are based an adaptive-agent modeling or a chaos complexity principles?

Responses to these questions showed that in the history of global model use in scenarios, early global models, produced scenarios based on their projections and there were no global models or studies in which the scenarios came first and produced the assumptions required for the model. When models are used this way, assumptions must be made about exogenous variables. Choosing these exogenous variables always involved judgment on the part of the modeler, and values and often based on an implicit scenario:

Implicit scenario → Exogenous assumptions → Modeling → Scenario construction based on model runs.

When the model was run, its output was consistent with the scenario on which the exogenous variables were based and the model provided quantitative estimates of the value of variables that were incorporated in the scenario. Hence:

Lookout panel developments → Scenario axes → Scenario construction → Exogenous assumptions → Modeling → Scenario quantification (Based on model runs).

Country scenarios:

- Canada: Energy Technology Futures
- Netherlands: Long-term outlook for Energy Supply
- The United Kingdom: Foresight Program – Energy Futures

The primary objective of the project has been the identification and highlighting of key opportunities and challenges posed by future changes in the supply and demand of energy and natural resources and those posed by ressures and the environment.

From this scenario exercise some robust messages are drawn concerning energy areas that appear to be of crucial importance in a majority of the scenarios analyzed. These areas include:

- network issues for distributed generation systems;
- development of more sustainable power generation technologies whether conventional, renewable or nuclear;
- increased efficiency in both generating technologies and end-use technologies;
- transportation technologies such as fuel cells and associated infrastructure;
- biomass and waste utilization;
- large scale energy storage;
- carbon dioxide sequestration;
- improved fossil fuel extraction (conventional and unconventional);
- regulatory mechanisms to facilitate emission trading, investment in energy efficiency;
- social science investigation of behavioral issues.

F. Three Exploratory Scenarios

However, before we set off to develop new scenarios, it is useful to clarify:

- The purpose of the work;
- The relevant questions that we want to address;
- The key uncertainties that deserve further exploration.

The purpose of these exploratory scenarios is to explore possible energy futures for energy and the environment over the coming 50 years. Although the perspective adopted is that of an organization of industrialized countries, the scope of the analysis must clearly be global.

The questions and key uncertainties that emerge from previous discussion are for the most part related to energy security, environmental damage and technological development.

- Will acknowledged energy resources actually be made available where and at the time they are needed?
- Will continuation of economic growth and satisfaction of our energy needs cause irreversible damage to the environment and thus compromise the welfare and safety of present and future organizations? And by way of what conditions can we avoid such an outcome?

Hence, the aim of these scenarios is to simulate discussion about environmental sustainability of our energy system, security of supply and energy technology development.

Scenarios to address these issues can be developed according to two alternative perspectives:

- We could explore different (but plausible) directions of development in our energy / economic systems and the type of implications they produce for energy security, climate change and related issues. If in the process some serious threats (energy supply disruptions, environmental collapse scenarios or others) emerge as a result, scenarios can help us prepare for these events, either to avoid them, or to control the damage after the fact;
- Scenarios can be developed in which specific undesirable events never occur and we can then work backwards to figure out what to do now to ensure such events never materialize. Constructing such scenarios requires analyzing what technologies might be needed and what policies might appropriately be implemented to avoid future damage.

Factors and trends that could be considered as "predetermined" or "unavoidable" were distinguished from those that are highly uncertain or depend on will. Predetermined elements / factors represent those elements that remain unchanged in all scenarios and listed among the common features of the scenarios developed. This way a list of seven main factors or drivers was isolated, which included (in descending order of importance):

- technology or speed or technological change particularly in the energy sector (both on the supply side and the demand side);
- attitudes and preferences with respect to the global environment;
- economic growth;
- population growth;
- globalization and degree of market openness;
- structure of power and Governance;
- global security issues.

In the scenarios developed here after the axis on technological change is seen to vary from fast to slow; the axis on attitudes and preferences with respect to the global environment varies from concerned to unconcerned.

The three scenarios developed were given names that characterize them immediately:

- clean but not sparking: describes a world of slow technological change, high concern for the global environment;
- dynamic and careless: describes a world of fast technological change, low concern for the global environment.
- bright skies describes a future of fast technological change, high concern for the global environment.

The technology areas may thus be ripe for policy development. On the energy supply side these include:

- energy efficiency improvement in supply technologies;
- advanced gas technologies in power generation; combined cycle gas turbines;
- gas transport, storage and liquefraction / re-gasification technologies;
- cleaner cool technologies (pulverized coal);

- CHP – Combined head and power;
- micro generation (gas);
- technologies for criteria polluant abattement (SOx, NOx, PM) ;
- stationary fuel cells;
- nuclear technologies, life extension and safety, new reactor concepts ;
- power generation from renewable sources: solar PV, solar thermal (including high temperature); wind; biomass; hydro-power;
- hydrogen production technologies (from coal, gas, nuclear or biological agents);
- technologies for hydrogen transport and long-term storage;
- power storage technologies;
- fuel cell power plants;
- carbon capture and storage for large-scale use;
- fusion

On the energy demand side they include:

- Energy efficiency improvement and conservation in all demand sectors: more efficient appliances; solar use of ICT to optimize performance;
- Fewer energy – and material – intensive manufacturing processes and services;
- Passive heating and cooling technologies and architectures in buildings: Building management systems:
  - Fuel efficiency improvement in conventional vehicles;
  - Biofuels;
  - LPG and methane;
  - Hybrid vehicles;
  - Fuel cell (gas or hydrogen fuel…..) cars;
  - Hydrogen storage technologies;
  - Electric vehicles;
  - Mass transit systems;
  - · - Advanced public transport systems;
  - Fuel cells for direct use of power;

Some technologies however appear mainly in the dynamic but careless scenario. These are:

- oil and gas, extraction and transport technologies;
- oil sholes and tar sands treatment technologies;
- enhanced oil recovery technologies;
- coal liquefaction and gasification technologies.

In normative scenarios, the perspective is different from that of explanatory scenarios: a normative scenario outlines a “desirable” vision of the future or a goal into the future.

To define this scenario’s normative characteristics, three main areas are particularly relevant.

These are:

- climate change mitigation;
- energy security and diversification;
- energy access.

In developing Climate Change Mitigation normative scenario exercise two alternative types of target were initially considered:

- an arbitrary global emissions reduction target with respect to 2000 levels (similar in structure to that proposed by the Kyoto Protocol);
- a target focusing on decarbonising the energy supply (for this case, calling for a given share of zero carbon sources in total world primary energy supply, by the year 2050).

Thus, the second alternative was chosen for this exercise. The selected target calls for this exercise. The selected target calls for a 60% share of “zero carbon” sources in total world primary energy supply, be the year 2050.

The issue of energy security and is a particularly by thorny one. Energy security has many faces. A number of threats have been encountered in recent history:

a) dependence on foreign energy sources;
b) dependence on sources that are gradually becoming depleted on a global bases (e.g. dependence on oil and gas);
c) dependence on geographic supply areas that are politically unstable (e.g. dependence on Middle Eastern Oil, risk of disruption in the production and shipment stage due to armed conflicts);
d) dependence on a gingle technology;
e) dependence on a limited numbers of delivery lines (one oil or gas pipeline);
f) market power of energy – exporting countries and is possible use as a political weapon.
g) market power of energy deliverers (e.g. truck drivers strikes in the case of gasoline and other liquid fuels delivery);
h) risk of market disruptions due to regulatory bottlenecks on mistakes (which may, interalia, cause insufficient levels of infrastructure investments).

The Sterling diversity index was originally developed to describe the level of diversity in electricity generation system. It is defined as:

$$\text{Div} = -\sum_i p_i \cdot \ln p_i \qquad (1)$$

where p_i represent the proportion of fuel type in a generation portofolio.

The index of OPEC oil dependence applies to the global scale of the problem represents the vulnerability of the system at a specific point in time. It is constricted as a composite index of three different parameters:

- Share of OPEC in world oil demand:
- An index of OPEC oil stock levels (including strategic stocks) at a given point in time.
- Excess OPEC crude oil production capacity

Access to energy is a powerful indicator of the level of development attained by a country population. As to specific target, we could somewhat arbitrarly set is as follows: to give access to electricity by 2050 to at least 95% of the world’s population.

V. THE UNION OF THE ELECTRICITY INDUSTRY - EURELECTRIC

EURELECTRIC is the sector association representing the common interests of the electricity industry at pan-European level, plus its affiliates and associates on several other continents.

For further information on EURELECTRIC activities, visit website: http://www.eurelectric.org which provides general informations about the association and policy issues relevant [related] to the electricity industry. The report is now entitled "Statitics and Prospects for the European Electricity sector". It contains historical referenced data for the years 1980, 1990, 2000, 2003, 2004 as well as forecast for the 2010, 2020 and 2030, concerning:

- The structure of the electricity industry;
- Trends in general economic indicators;
- Peak demand and load management;
- Medium and long term generating;
- Programmes and prospects;
- Sector electricity consumption;
- Energy Balance for electricity
- Fuel consumption in and emissions from electricity sector.

Another report showing a picture of the continental European System from a today's operational perspective is published by UCTE in its yearly System Adequacy Forecast and can be downloaded in the section "Publication" at http://www.ucte.org.

UCTE is producing its system Adequacy Reports to give information concerning the future situation from a today's operational perspective without considering major macroeconomic changes or political trends and to provide to market players and public authorities early warning signals concerning potential needs for new investments.

These assumption are taken to best meet the aims of the Association focusing on providing a complete overall view on the power system evolution and investigating system adequacy and not only generating capacity adequacy (in order to match the system load evolution).

Two scenarios are considered in order to cover the higher uncertainties on future generation capacity at such time horizon:

Scenario (A) "Conservative": only new projects considered as "firm", estimated on the basis of data available to TSO's, are taken into account (as long as they are known) and decommissioning projects. The aim of this scenario is to highlight potential unbalanced without any new further investments decisions.

Scenario (B) "Best Estimate": results from TSO's estimations of generation developments taking into account: national generation development plus appliance to European directives (renewable), applications for grid connection. The aim of this scenario is to give an estimation of potential future development induced by market signals and adequate incentives for investments.

Therefore, concerning generating capacity commissioning only those new projects are take into account, which are considered as sure, according to the informations TSO receive (connection agreement signed or going to be signed, new power plants taken into account in the long-term plan for transmission system development, or signature of other agreements according to country rules).

As far as shutdowns are considered, the best estimation is given, being as close as necessary to the present situation.

The EUROPROG report of EURELECTRIC is based on the best view of country experts of what is likely to occur in each country with respect to the plant demand balance, taking into account recent trends and projections of economic, social, environmental and technological development.

The capacity projected allows for growth in demand and the adaptation of a national plant capacity margin based on historical experience, which is sufficient to meet the security standards regarded at the norm in each country. This may mean the allowance for closures which have not been notified and the building of new plant which does not exist or under construction.

Therefore, both reports are complementary and follow different objectives with different approaches. However, the consistency is closely checked between both involved associations, through regular contents to make sure that the best data quality can be reached in all reports.

The volitional differences in the datasets are based on:

- Different points of view (pure TSO information versus a more general electricity industry view)
- Different assumptions for forecasting value (estimation from TSO reality versus global industrial estimations)
- Different time frames;
- Minor methodological differences.

VI. CONCLUSIONS

1. It is clear that the future is not simply something already predetermined that we must accept blindly: rather, it is open and to a large extent determined by the course of actions we decide to take. For this reason, we need to look at the future and its uncertainties in an articulated fashion, developing specific tools to consider both how the future might unfold if we do not act and how we might like the future to unfold if action were to be talken.

2. As demonstrated on valuable intellectual exercise for looking into an uncertain future involves the development of "scenarios" intended as logical and plausible conjectures about how fundamental drivers will affect global societies, economics, resource use and the environment. The literature review shows a multiplicity of scenarios, conducted as different scales ranging from the national to the global scale, with different time horisonts and with a focus on different strategic isssues.

3. Exploratory scenarios help prepare for events that, without representing a straight-line continuation of past trends, are plausible and entirely possible. Exploratory scenarios can help a lot to accelerate and calibrate the response to new developments, as well as providing a strategic framework technology development policy.

4. Normative scenario has, as its goal, the evolution of a desirable future rather than a future inexorably imposed upon us by the inertie of system. Building a normative scenario requires the creators to clearly define the desirable characteristics of their future, and to express this future in terms of measurable targets.

5. The use of such a scenario process lies as much in the issues it requires us to confort as the precise details is generates. The future will not look exactly like the one envisioned: other priorities will intercede and national conditions and circumstances will dictate the specifics of the energy policies that may be adopted. But such a process of interating around scenarios can provide valuable guidance as to what we must do – collectively and individually – to achieve the set policy goals.

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