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Diffusion of Emerging Technologies for Sustainable Development: Prospective Assessment for Public Policies

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Abstract

Emerging technologies based on biotechnology, nanotechnology, information and communication technologies (ICT), and green chemistry will shape the future of some industries and will transform many others. In many cases, these technologies will determine the development and restructuring of industries as never before. These changes, in turn, will promote debates and revisions of current regulatory frameworks and corporate business models. This paper - which is based on a prospective study carried out by the authors in 2010 - emphasizes the importance of understanding and anticipating movements of driving forces, trends and critical uncertainties at global level, which will influence the diffusion of emerging technologies into industrial processes and business models concerning seven societal sectors. The purpose of this paper is to describe the evolutionary trajectories of these sectors, based on diffusion of the so-called emergent technologies in a time horizon of 20 years.

Keywords: emerging technologies; technology foresight; prospective studies; sustainable development; public policies.

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Introduction

Emerging technologies based on biotechnology, nanotechnology, information and communication technologies (ICT), and green chemistry will shape the future of some industries and will transform many others. In many cases, these technologies will determine the development and restructuring of industries as never before. These changes, in turn, will promote debates and revisions of current regulatory frameworks and corporate business models.

Will the new technologies findings be focused on radical innovative solutions that will generate new businesses? Or will technological advances be more incremental, concerning the improvement of existing technologies and businesses? Which new industrial configurations will emerge as a result of the diffusion of innovations related to biotechnology, nanotechnology, green chemistry, and ICT? And at what pace? To what extent the so-called emergent technologies will create or resolve ethical dilemmas?

These are questions for which planning based on prospective studies, particularly prospective scenarios, offers a robust conceptual framework. In fact, prospective scenarios are addressed for complex and highly volatile environments, organizing and revealing uncertainties and trends concerning the analysis of potential impacts of emerging technologies on current and future industrial configurations in long-term horizons (Georgantzas and Acar, 1995; Schoemaker and Van der Heijden, 1992; Van der Heijden, 2005; Schwartz, 1996; 2004). Prospective studies help managers to understand the commercial potential of emerging technologies and to use this understanding to formulate objective and consistent policies and programs for the consolidation of new industrial configurations. They also contribute to the revision of appropriate regulatory frameworks surrounding the diffusion and incorporation of new technologies in products, processes and services in the future.

From this perspective, it was developed a prospective study titled "Industries of the Future and Emerging Technologies", whose general objective was to analyze the potential impacts of emerging technologies on existing and future industrial settings, considering a time horizon of 20 years. More specifically, the study sought to: (i) analyze previous global and prospective studies focused on selected sectors, as well as national and international reports on the current status and future development of the so-called emerging technologies - nanotechnology, biotechnology, information and communication technologies, and green chemistry; (ii) discuss and describe projected trajectories of the selected sectors in two periods (2010-2020 and 2020-2030), (iii) identify the potential impacts of emerging technologies in building future industrial configurations (associated with the selected sectors); and (iv) analyze, in a global context, the implications of potential changes for Brazil focusing on the future sectorial trajectories.

The purpose of this paper is to present the main findings of this prospective study carried out by the authors in 2010, emphasizing the importance of understanding and anticipating the global driving forces and the key factors that directly influence the diffusion of emergent technologies into industrial processes concerning eight sectors, namely: health; agro-industries; forest systems; energy; buildings; mobility; telecommunications; and materials. Besides, this paper reinforces that there are certain sector- and technology-specific patterns of innovation that need to be taken into account in public policies aligned to a vision for a sustainable future. It was assumed that the evolution of these sectors based

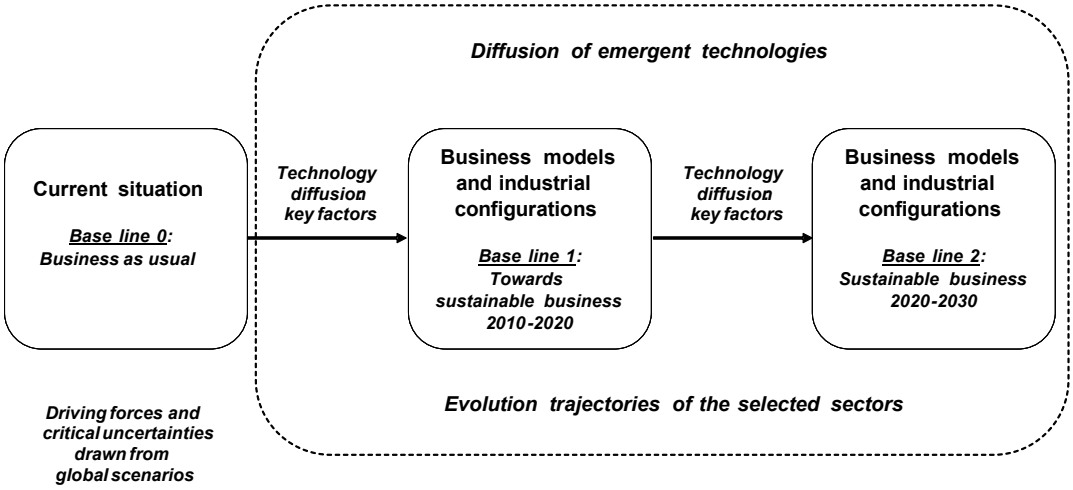

Figure 1. Basic structure of the conceptual model

on emergent technologies' diffusion and respective public policies would have a great impact on the achievement of a vision for a sustainable future in 2030.

Figure 1 represents the conceptual model developed and adopted in the prospective study. It integrates four basic elements: (i) the current situation as a baseline (business as usual scenario); (ii) diffusion of innovations based on emerging technologies in the selected sectors, focusing on the mentioned new technologies; (iii) business models and industrial configurations along the period from 2010 to 2020, and (iv) business models and industrial configurations aligned to a vision for a sustainable future in 2030 (period from 2020 to 2030).

From the analysis of the current situation, sectorial outlooks were described as a basis for constructing the "business as usual" scenario (Base line 0, in Figure 1). The analysis of long-term global scenarios led to the identification of the main driving forces, trends, and critical uncertainties that would influence the business models and industrial configurations concerning each sector along the period of 2010 – 2020.

In the sequence, with the adoption of prospective scenario's methodologies reviewed in the first phase of the research (Godet, 2001; Schoemaker, 1992; Van der Heijden, 2005; Schot, 1998; Georgantzas and Acar, 1995), it was possible to describe the evolution trajectories concerning the eight sectors for the first ten years. The 2020 future scenes for these sectors were translated into new baseline (Base line 1, in Figure 1). From these new baseline and considering the diffusion of the so-called emergent technologies in a time horizon of 10 years, the evolution trajectories of the above-mentioned sectors were designed within the perspective of a sustainable future in 2030 (Base line 2).

As already mentioned, the prospective study's scope encompasses eight sectors, and four groups of emergent technologies. The selected sectors include health; agro industries; forest systems; energy; building; mobility; telecommunications; and materials. For developing a cross-impact analysis focusing on the diffusion of emerging technologies on industrial configurations associated to the selected sectors, the following emerging technologies were considered: biotechnology; nanotechnology; green chemistry; and information and communication technologies (ICT).

Methodology

Aligned with the qualitative model represented in Figure 1, a schematic overview of the prospective study development is showed in Figure 2. It comprised three main phases: (i) conceptual; (ii) participative; and (iii) conclusive.

The "Conceptual phase" encompassed: (i) bibliographic and documentary reviews covering the research central themes and prospective studies; (ii) selection and analysis of systemic prospective studies at global level; and (iii) identification and analysis of prospective studies focusing on the technologies and sectors selected.

Concerning the bibliographic review, the following theoretical frameworks were considered: (i) dynamic approaches to innovation systems (Geels, 2004; 2005; 2008; Breschi and Malerba, 1998; Malerba, 2004; Johnson, 1998; Bergek, 2002; Bergek and Jacobsson, 2003; Carlsson and Jacobsson, 2004; Edquist, 2004); (ii) technology assessment approaches, in particular its constructive perspective (Smits et al. 1995; Sanmartín and Hronszky, 1994; Todt, 2002; Schot, 1992; Sanmartín and Ortí, 1992; Schot and Rip, 1998; Shrader-Frechette, 1985); and (iii) scenarios building (Van der Heijden, 2005; Schoemaker and Van der Heijden, 1992; Schwartz, 1996; 2004), with special attention to cross-impact analysis as proposed by Godet (2001).

In relation to the analysis of systemic prospective studies at global and sectorial levels, several documents were selected and reviewed with an attempt to: (i) mapping the driving forces that will influence the diffusion of emergent technologies and the evolution of sectorial trajectories; (ii) identifying the main trends and critical uncertainties drawn from multiple scenarios; and (iii) identifying key issues concerning emergent technologies advances, new business models and future industrial configurations.

By way of illustration, three prospective studies at global level were consulted and reviewed: (i) "Mapping the Global Future 2020", a study prepared by the U.S. National Intelligence Council, in 2002, (ii) "Global Scenarios 2025", which were prepared by Shell in 2005; and (iii) "Global Scenarios 2065", proposed by the Global Scenario Group as part of the normative study "Great Transition", published in 2002. At sectorial level, the main reference adopted was a prospective study titled "Vision 2050: the new agenda for business", which was published in 2010 by the World Business Council for Sustainable Development.

For the third step of "Conceptual phase" a structural analysis concerning the focused system was carried out using the MICMAC method developed by Lipsor, in France (Lipsor, 2010). According to Lipsor (2010), this form of analysis describes the system using a matrix which combines the constituent components of the system. The MICMAC method helped to: (i) identify the main variables which were both influential and dependent: those which were essential to the evolution of the system; (ii) map the inter-relationships and relevance of these variables for explaining the evolution of the system; and (iii) reveal the causal chain of the system, comprising the set of eight selected sectors, in this case.

The identification of key drivers by using MICMAC method seeks to improve the understanding of complex systems and to highlight what are the variables that need to be considered a priori. The MICMAC method consists of a program of matrix multiplication applied to direct relationships matrix, which allows to study the diffusion of impacts throughout the influence chain and feedback and, consequently, to rank more accurately the system variables. Its goal, as mentioned before, is to highlight the driving forces (the most influential) and also the most dependent, called "depending variables". Figure 3 represents the "influence-dependence chart", according to MICMAC method developed by Lipsor, in France (Lipsor, 2010).

Fundamentally, the structural analysis method comprised: (i) identification and description of key variables; (ii) expert judgment about the relationships between variables within a structural matrix; (iii) classification of variables adopting the MICMAC method proposed by Michel Godet (Lipsor, 2010); and (iv) design of the influence-dependence chart (Figure 3) and its corresponding influence graphs, which provided all the information needed to build the causal chain of the system.

In the "Participative phase" an expert panel was held in Brasilia in September 2010 and was attended by more than 60 experts from Brazilian government, academy, and industry. The objectives of this workshop were: (i) to validate the partial results from the conceptual phase; (ii) to build a vision for a global sustainable future, concerning the eight selected sectors (time horizon: 2030), (iii) to design the evolution trajectories of the selected sectors in a horizon of 20 years, considering key factors that will influence the diffusion of emergent technologies in two periods of time (2010-2020: and 2020-2030); and (iv) to analyze the implications for Brazilian public policies, corporate strategies and academic R&D orientation towards the 2030 vision for a sustainable future. Finally, in the "Conclusive phase", the results of previous phases were consolidated in a final report entitled "Prospective study on industries of the future and emerging technologies: a vision for a sustainable future" (CGEE, 2010, in Portuguese). The present paper summarizes the main findings presented in that document.

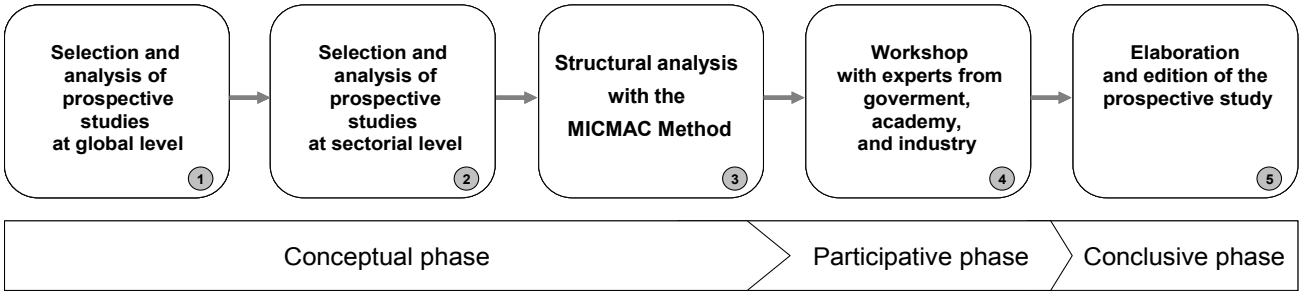

Figure 2. Development of the prospective study: a schematic overview

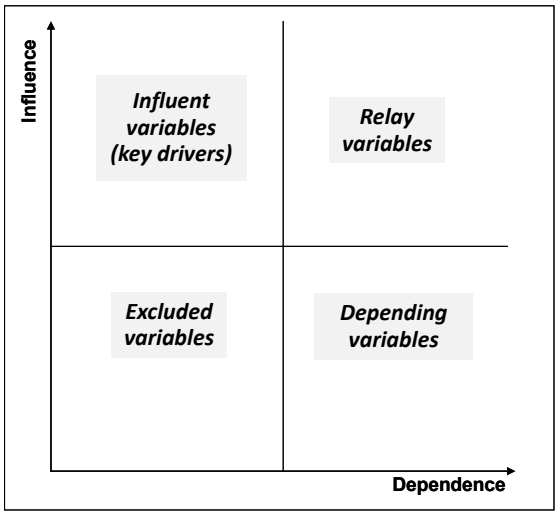

Figure 3. Influence-dependence chart, according to MICMAC method. Source: Lipsor (2010).

Results of the prospective study

This section presents the results of the prospective study, focusing on its conceptual and participative phases (See Figure 2). Considering the qualitative nature of the model and the methods of analysis that were employed, the research focus was on qualitative results and related insights. To accomplish this, we considered crucial the use of the MICMAC tool proposed by Michel Godet (Lipsor, 2010), given its capacity for reconstructing the causes of any result of the participative phase by backtracking the impact flows within a given configuration.

During the conceptual phase, it was possible to identify a preliminary list of key variables based on the analysis of five global prospective studies conducted by recognized institutions in this field. Table 1 presents a preliminary list of variables based on the analysis of those studies.

The understanding of the key variables that will condition the diffusion of emerging technologies and the evolution of industrial configurations in 20-year horizon was considered a key step in this prospective study. Content analysis of the five global studies listed in Table 1 allowed us to identify the main issues directly associated with emerging technologies and future industrial configurations.

The first stage consisted in listing all the variables which characterize the system under study and the variables concerning its environment. The final result was a list of internal and external variables for the system studied. The application of the MICMAC tool helped to validate this list, confirming the adequacy of the original selection. A detailed explanation of variables was indispensable to follow up the structural analysis and recognize relationships between the variables. Objective and clear definitions helped to identify former changes, variables which started the evolutions, to characterize the present situation and to recognize trends or future ruptures.

Tables 2 and 3 show respectively the context variables (external) and the system variables (internal) and their respective definitions. As a result, an "analytic grid" for the prospective study was established. It comprised seven external variables (associated to the context) and ten internal variables (related to the system).

Prospective study	Author	Driving forces
"Davos", "Pax Americana", "A New Caliphate", and "Cycle of Fear"	National Intelligence Council	- Emergence of new global players; - Impacts of globalization; - New challenges concerning global governance - Pervasive insecurity; - Transmutation of international terrorism.
"Low Trust Globalization", "Open Doors", and "Flags"	Shell	- Market rules; - Social requirements; - State Regulations and control.
"Conventional Worlds" , "Barbarization", and "Great Transitions"	Global Scenario Group	- Population; - Economy; - Environment; - Social equity; - Technology; - Conflicts (global governance).
"The Great Transition"	Global Scenario Group	- Values and knowledge; - Demographic and social changes; - Economy and global governance; - Technological changes and environmental protection.
"Vision 2050"	World Business Council for Sustainable Development	- Human development, with low ecological impacts; - Values and behaviors; - Economy; - Changes in economic sectors: agriculture, forestry, energy, construction, mobility, and materials

Table 1. Driving forces identified in selected global prospective studies

For the classification of external and internal variables listed in Tables 2 and 3, a squared matrix (variables x variables) was fulfilled by experts from Brazilian Science and Technology (S&T) Community specially invited by CGEE for this purpose. The judgments were based on analysis of previous prospective studies, as follows: (i) five global prospective studies, and (ii) several sectorial prospective studies. The main results from the conceptual phase were: (i) a list of key variables that drive the evolution of the system towards the desired direction – a sustainable future; (ii) a list of relay variables, (iii) a list of depending variables; (iv) an influence-dependence chart (Figure 4); and (v) a corresponding influence graph, showing the relationships between variables (Figure 4).

The four key variables are the following: values change; global governance; economic growth; and population growth. The five relay variables are: human development; regulation; technology diffusion; climate change and environment. Finally, the eight depending variables are directly associated to the selected sectors.

Figure 4 represents the influence-dependence chart, which formed the basis for scenarios' building during the "Participative phase", together with its corresponding influence graph (See Figure 2).

All the objectives of the "Participative phase" were achieved. The results and discussions from the Brasília expert panel led to: (i) validate the partial results from the conceptual phase; (ii) build a vision for a global sustainable future, focusing on eight selected sectors; and (iii) design future sectorial trajectories in two periods of time (2010-2020, and 2020-2030).

Due to space constraints, only the results for the energy sector are shown in this paper (See Table 4). The findings concerning the remaining sectors can be found in the final report of the prospective study (CGEE, 2010).

Variable	Description	Analytical dimension
Value changes	Changes observed in values, behaviors and lifestyle of society at a given period of time.	Social
Human development	Measured by Human Development Index (HDI), which is based on four criteria: life expectancy at birth, mean years of schooling, expected years of schooling and gross national income per capita. The HDI makes it possible to track changes in development levels over time.	Social
Economic growth	Measured by Gross Domestic Product (GDP), which is the market value of all officially recognized final goods and services produced within a country in a given period of time.	Economic
Global governance	It is the political interaction of transnational actors aimed at solving problems that affect more than one state or region when there is no power of enforcing compliance.	Political
Demographic growth	The size of a population increases when there are more births than deaths (natural balance) and more migrants arriving than departing (migratory balance).	Social
Climate changes	Statistically significant variations in the distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average weather conditions, or in the distribution of weather around the average conditions (i.e., more or fewer extreme weather events).	Environmental
Environmental protection	Policies and procedures aimed at conserving the natural resources, preserving the current state of natural environment and, where possible, reversing its degradation.	Environmental

Table 2. Context variables

Conclusions

The aim of this paper was to emphasize the importance of understanding and anticipating the global driving forces and the key factors that directly influence the diffusion of emergent technologies into industrial configurations and processes. The prospective study focused on eight sectors – health; agro industries; forest systems; energy; buildings; mobility; telecommunications; and materials – and demonstrated the usefulness of a variant of cross-impact method for building scenarios in uncertain environments. It revealed four driving forces, namely values change; global governance; economic growth; and population growth; five relay variables (human development; regulation; technology diffusion; climate change and environment), and eight depending variables, which are directly associated to the selected sectors. The scenario-building exercises developed during the participative phase have generated important insights concerning challenges of current situation and have also showed which new technologies are relevant for governments, companies,

Variable	Description	Analytical dimension
State regulation of emergent technologies and new markets	State regulation and oversight of emerging technologies should be based on the best available scientific evidence. Adequate information should be sought and developed, and new knowledge should be taken into account when it becomes available. It should be based on an awareness of the potential benefits and the potential costs of such regulation and oversight, including recognition of the role of limited information and risk in decision making.	Political
Technology diffusion	Technology diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system. The diffusion of an innovation occurs through a five–step process: awareness, interest, evaluation, trial, and adoption.	Technological
Healthcare	Healthcare is the sector of the economy made up of companies and organizations that specialize in products and services related to health and medical care.	Economic
Agroindustries	Agroindustries comprises the businesses collectively associated with the production, processing, and distribution of agricultural products.	Economic
Forest systems	Defined as an ecosystem or assemblage of ecosystems dominated by trees and other woody vegetation.	Economic
Energy	Comprises processes, products and services for the generation and supply of energy from various sources: oil and natural gas; hydroelectric, nuclear, and alternative sources (solar, wind, hydrogen, among others).	Economic
Telecommunications	Telecommunications services include transmission and emission or reception of multimedia information by any electromagnetic process.	Economic
Buildings	Includes activities ranging from architecture to engineering, through materials and equipment. Most of the reducible emissions are to be found in the increase of energy efficiency in building.	Economic
Mobility	Set of activities including processes, products and services for geographic mobility.	Economic
Materials	Comprises the production, use and reuse of materials in various sectors of the economy.	Economic

Table 3. System variables

and other stakeholders to face the challenges. The scenarios designed for two periods (2010-2020, and 2020-2030) highlighted how the emergent technologies (considering social, economic, and political forces) can support a sustainable future. They were developed during an expert panel involving more than 60 representatives of the Brazilian government, universities, and industrial sectors.

Focusing on the case illustrated in this paper – the energy sector in a global context – we could identify a set of trends and relevant issues for public policy formulation, as follows: (i) international consensus on effective management of greenhouse-gas emissions; (ii) definition of a global carbon price in the carbon market; (iii) effective policies towards costs reduction of energy generation and efficiency improvement of alternative sources of energy generation; (iv) energy consumption reduction campaigns and information diffusion concerning environmental and economic benefits of efficient energy use; (v) education about energy consumption habits within the context of overall energy efficiency; (vi) safety tests and demonstration for public acceptance of promising technologies such as carbon capture and sequestration (CCS), nuclear power and biofuels; and (vii) the regionalization of energy solutions.

The main findings of the prospective study reinforced that there are certain sector- and technology-specific patterns of innovation that need to be taken into account in public policies and corporate strategies aligned to a vision for a sustainable future. It was assumed that the evolution of these sectors based on the diffusion of emergent technologies would have a great impact on the achievement of the vision for a sustainable future in 2030.

We believe that the results of the prospective focused in this paper are useful for developing public policy programs intended to stimulate and support innovations concerning biotechnology, nanotechnology, green chemistry, and ICT advances towards a sustainable future. They could also help companies to establish their low carbon corporate strategies, and also academic institutions to define their sustainable R&D guidelines. The scenarios highlighted how a sustainable future can be supported by emergent technologies, considering social, economic, and political forces, and can provide decision-makers with information relevant to their future strategic choices.

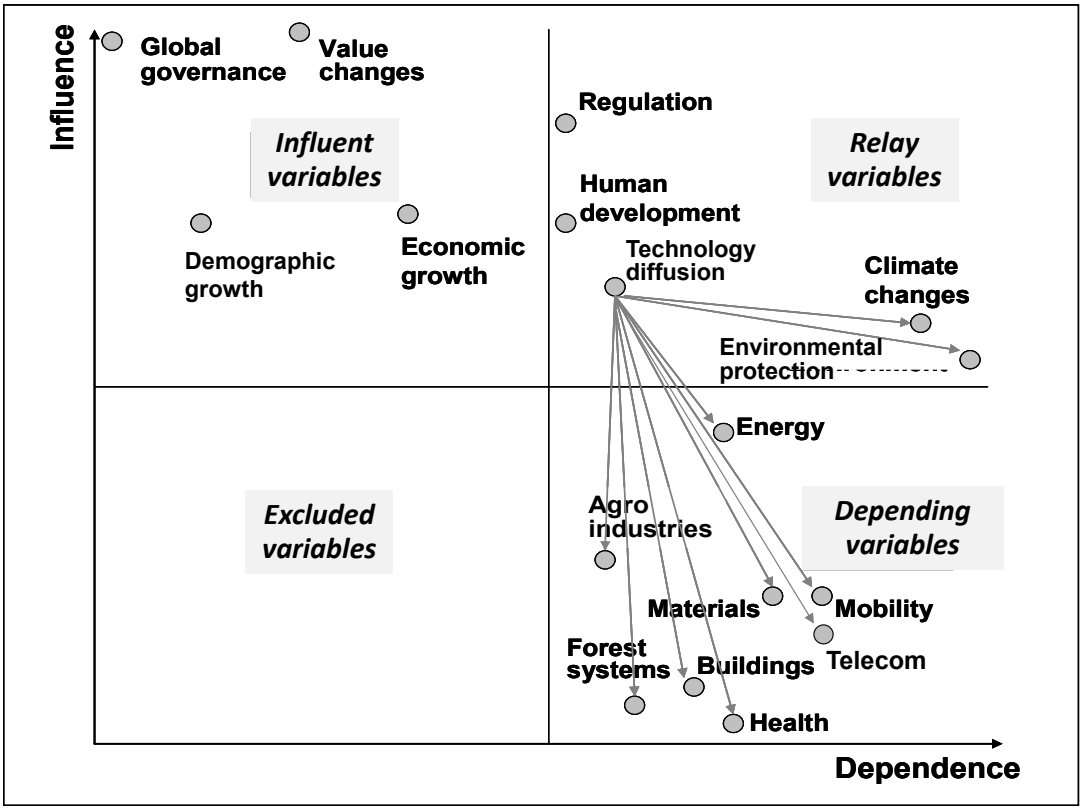

Figure 4. Diffusion of emerging technologies: influence-dependence chart

Item	Description
Current situation: main challenges	- International consensus on the need for an effective global greenhouse gas management system. - Multilateral and international discussions to set a price of carbon at a global level. - Effective policies to reduce the production costs of energy and to increase the efficiency of other forms of energy generation. - Intensive use of incentive mechanisms and guidelines concerning eco-efficiency (globally and locally). - Education on energy consumption habits regarding cost savings and environmental benefits related to eco-efficiency. - Feasibility demonstration and risk assessment for regulatory and public acceptance of promising technologies such as carbon capture and sequestration (CCS), nuclear and biomass. - Regionalization of energy solutions based on emergent technologies.
Diffusion of key emergent technologies	- Biotecnology: biofuels; biorefineries (biomass fractionation and conversion); microorganisms' biotechnology; synthetic biology, enzyme and fermentation technologies. - Nanotechnology: nanomaterials for renewable energy devices, including photovoltaic cells, fuel cells, wind power, among others; nanostructured catalysts for the petroleum industry and ethanol production; nanomaterials for ethanol and bioethanol production and reuse of biomass; new and more efficient lighting systems (both organic and inorganic LEDs); nanotechnology for power generation and storage (nano batteries and capacitors); hydrogen technologies. - Information and communication technologies: systems for detecting leaks of chemicals (bio-nano-ICT convergence); new algorithms for digital Programmable Logic Controllers (PLC); new algorithms for power line communications; smart grids; new algorithms and artificial intelligence for seismic activities; systems for detecting potentially dangerous gases; and basic sensory mesh networks. - Green chemistry: remediation processes applied to fossil raw materials.

Item	Description
Scenario 2010-2020	Fossil fuels: (i) the oil and natural gas industry will continue to be dominated by cartels at a global level; rising costs of exploration and production (remote reserves); and search for technological solutions concerning alternative sources of energy; (ii) increasing use of coal as energy source and search for new technological solutions towards cleaner processes regarding this energetic source; (iii) increasing consumption of natural gas, and search for technological alternatives for enhancing its use, especially regarding their chemical transformations; and (iv) potential exploration of shale and bituminous sources as well as oil reserves of very low API level, depending on the viability of alternative technological solutions. Energy renewable sources' fuels: (i) moderate growth of hydroelectric generation by 2020, (ii) continued growth of small-scale hydroelectricity plants by using existing, proven technologies; (iii) potential growth of solar thermal energy, by using existing, proven technologies; (iv) large potential growth of solar energy, due to several safe and economic technological innovations; (v) increasing use of some types of microbial biomass as feedstock for biofuels, like micro algae; (vi) rapid growth of ethanol production as fuel, which could be even greater due to new technologies diffusion (especially, lignocellulosic ethanol); (vii) huge growth of bio-jet fuels due to existing proven technologies (biodiesel) and those in development (BTL); (viii) utilization of waste based on densification technologies (pyrolysis) and gasification (BTL), as well as on alternative biotechnology applications, and (ix) strong prospects for profitability and growth of wind power, particularly in specific geographic conditions. Growth is fuelled by rapid technological development enabling large-scale energy production at a competitive cost per produced kWh. Other energy sources: (i) potential growth of nuclear energy, by using safe and proven technologies; (ii) high growth (immediate and continuous) regarding the use of eco-efficiency technologies; (iii) moderate growth of hydrogen as energy source, mainly observed in specific market niches.
Scenario 2020-2030	Significant decline of greenhouse gas emissions. Competitiveness of solar energy. Increasing use of clean energies in developing countries. Nuclear power generation will remain crucial for mitigating climate changes in this period. There will be stagnation concerning the generation of hydroelectric power by 2030. Particularly, in relation to fossil fuels, it can be mentioned: (i) potential change in the rate of growth of oil supply due to the emergence of new remote reserves, e.g. pre-salt in Brazil; (ii) potential change in the rate of growth of coal use, due to the diffusion of alternative technologies for the application of coal-type coal to liquids (CTL), dimethyl ether (DME) and in situ gasification; (iii) increasing consumption of natural gas, with potential changes in its growth rates, due the emergence of alternative technologies for implementing such dimethyl ether (DME) and GTL offshore, and (iv) exploration of the potential use of shale and bituminous sources, due to the diffusion of disruptive alternative technological solutions.

Table 4. Scenarios and diffusion of emergent technologies: focus on the energy sector

References

BERGEK, A. (2002). Shaping and exploiting technological opportunities: the case of renewable energy technology in Sweden. Department of Industrial Dynamics. Chalmers University of Technology, Göteborg.

BERGEK, A., Jacobsson, S. (2003). The emergence of a growth industry: a comparative analysis of the German, Dutch and Swedish wind turbine industries. In: Metcalfe, S. & Cantner, U.: Change (Eds.) Transformation and Development. Heidelberg Physica-Verlag, p. 198-228.

BRESHI, S., Malerba, F. (1998). Sectorial innovation systems: technological regimes, schumpeterian dynamics, and spatial boundaries. In: Edquist, C. (ed.). Systems of innovation: technologies, institutions, and organizations. London: Pinter. p. 130-156.

CARLSSON, B., Jacobsson, S. (2004). Dynamics of innovation systems: policy-making in a complex and non-deterministic world. In: Proceedings of International Workshop of Functions in Innovation Systems. University of Utrecht.

CENTRO De Gestão E Estudos Estratégicos (2010). Prospective study on industries of the future and emerging technologies: a vision for a sustainable future. Mimeo. Brasília: CGEE.

EDQUIST, C. (2004). Systems of innovation: perspectives and challenges. In: Fagerberg, J. Mowery, D.C., Nelson, R.R. (Eds.) The Oxford Handbook of Innovation, Oxford: Oxford University Press.

GEELS, F.W. (2004). From sectorial systems of innovation to socio-technical systems: insights about dynamics and change from sociology and institutional theory. Research Policy, v. 33, n. 6/8, p.898–920.

GEELS, F.W. (2005). Technological transitions and system innovations: a co-evolutionary and socio-technical analysis, Cheltenham: Edward Elgar.

GEELS, F.W., Schot, J.W. (2008). Typology of sociotechnical transition pathways. Research Policy, v. 36, n. 3, p. 399–418.

GEORGANTZAS, N. C., Acar, W. (1995). Scenario-driven planning: learning to manage strategic uncertainty. Westport, Connecticut: Quorum Books.

GLOBAL Scenario Group (2002). Great transition: the promise and lure of the times ahead, GSG.

GODET, M. (2001). Manuel de prospective stratégique: tome 1 – une indiscipline intellectuelle. 2. ed. Paris: Dunod.

JOHNSON, A. (1998). Functions in innovation system approaches. Department of Industrial Dynamics, Chalmers University of Technology, Göteborg. Working paper.

LIPSOR (2010). Micmac: se poser les bonnes questions et identifier les variables clés. Laboratoire d'Investigation en Prospective, Stratégie et Organisation. 2010. http://www.3ie.fr/lipsor/micmac.htm [Accessed April 19, 2013].

MALERBA, F. (2004). Sectorial systems of innovation: basic concepts. In: Malerba, F. (ed.) Sectoral systems of innovation, Cambridge: Cambridge University Press, p. 9-41.

NATIONAL Intelligence Council (2002). Mapping the Global Future 2020. New York: Council of Foreign Relations.

SANMARTÍN, J., Hronszky, I. (eds.) (1994). Superando fronteras: estudios europeos de ciencia tecnología-sociedad y evaluación de tecnologías. Barcelona: Anthropos.

SANMARTÍN, J., Ortí, A. (1992). Evaluación de tecnologias. In: Sanmartín, J et al (eds). Estudios sobre sociedad y tecnología. Barcelona: Anthropos.

SCHOEMAKER, P. J. H., Van der Heijden, C. A. J. M. (1992). Integrating scenarios into strategic planning at Royal Dutch/Shell: case study. Planning Review, May/June 1992, p. 41- 46.

SCHOT, J. W. (1992). Constructive technology assessment and technology dynamics: the case of clean technologies. Science, Technology & Human Values, v.18, n.1, p. 36-56.

SCHOT, J.W., Rip, A. (1998). The past and future of constructive technology assessment. Technology Forecasting and Social Change, v.54, p.251-268.

SCHWARTZ, P. (1996). The art of the long view: planning for the future in an uncertain world. New York: Doubleday Pub.

SCHWARTZ, P. (2004). Inevitable surprises. New York: Gotham Books.

SHELL (2005). Global Scenarios 2025. http:www.shell.com [Accessed April 19, 2013].

SHRADER-Frechette, K. (1985). Technology assessment, expert disagreement, and democratic procedures. Research in Philosophy & Technology, v.8, JAI Press, Nueva York.

SMITS, R., Leyten, J., Den Hertog, P. (1995). Technology assessment and technology policy in Europe: new concepts, new goals, new infrastructures, Policy Sciences, v. 28, p.281-299, 1995.

TODT, J. O. (2002). Innovación y regulación: la influencia de los actores sociales en el cambio tecnológico: el caso de la ingeniería genética agrícola. 293 p. Tesis Doctoral. Universitat de Valencia.

VAN DER HEIJDEN, K. (2005). Scenarios: The art of strategic conversation. 2.ed. West Sussex: John Wiley & Sons.

WORLD Business Council For Sustainable Development (2010). Vision 2050: the new agenda for business. 2010.