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Major Risks and Public Initiative

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As former acting Chair of the CAE (Council of Economic Analysis), and with the full agreement of the current Chair, I present this report on major risks, which was begun before the changes to the members of the Council.

Chernobyl, the Toulouse AZF chemical factory explosion, Xynthia, Fukushima and many other tragedies have been added to the list of major crises of a systemic nature with drastic human and social consequences. In recent times, in response to the global crisis, economists have studied systemic risks of a financial nature in greater depth. In this case we are concerned with other kinds of potentially or actually systemic risks, which are often brought up because of their appearance in media headlines, without having been the subject of systematic investigation such as that set out here. The report precisely defines its subject –major risks– which it groups together in three categories: natural risks, technological risks and nuclear risks. Indeed, part of the analysis consists of emphasising and weighing up the specific differences and points of agreement between, as well as within, each of these categories.

Human, economic and financial issues are highlighted, and more broadly, social questions. It is enlightening to understand the distinction between factors that fall within the realm of chance or inevitability and those that are influenced by individual behaviours and collective choices, and therefore attributable to humankind. Some of the answers, and only some, are to be found in the economists' and managers' «tool box», and decision theory, which falls within the scope of both professions, needs to be taken further. The approach to these issues needs to be resolutely multidisciplinary –as it is in this report.

The various moments of major risks are addressed: ex ante *or "before the event" and* ex post or "after the event" *and the transition from one to the other, as well as everything related to the mechanisms of liability and insurance. The various facets are dealt with in a meticulous and, above all, very practical manner. At the end of this analysis, which marks a milestone and that many researchers and (public and private) decision-makers will need to take into account in the future, the authors make operational recommendations concerning either assessment (for example concerning the development of indicators), prevention, or insurance cover for major risks, to the attention of the national and European authorities.*

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Major risks, is understood to mean risks associated with events whose undesirable consequences, for mankind and/or the environment, are of exceptional seriousness. This definition should not be further restricted to events of an extreme physical intensity or very low frequency, because such is not always the case. Among major risks of a civil nature, –the only type considered in this report–, a distinction is made between *natural risks*, such as river and coastal floods, e.g. the one caused by cyclone Xynthia in 2010, *industrial technological risks*, e.g. explosions like the AZF disaster in 2001, *nuclear risks* (which are dealt with separately because they involve the phenomenon of radioactivity), as illustrated, outside of France, by the disasters of Three Mile Island (1979), Chernobyl (1986) and Fukushima (2011), *sanitary* risks, of which the bovine spongiform encephalopathy (BSE) crisis was a perfect example, *food safety* risks, sometimes connected to the former –as in the case of BSE– and finally *climate risk* and *terrorism*, which are less clearly defined owing to their recent appearance in the public consciousness.

This report from the CAE begins by dealing with major risks broadly speaking (section 1), but only goes into detail with regard to natural, technological (the adjective "industrial" henceforth being understood) and nuclear risks. Moreover, the report only studies French territory (though without neglecting French overseas territories). It tackles these three risks in a transverse manner, through the prisms of geography and technology (section 2) and institutional and legal history (section 3), before finally giving a normative assessment and recommendations (section 4). The principal document is accompanied with nine specialised supplements. These are the work of A. Quantin and D. Moucoulon (*Caisse centrale de réassurance*), V. Sanseverino-Godfrin (*Mines-Paritech*), C. Grislain-Letrémy and B. Villeneuve (*Paris-Dauphine University*), A. Schmitt and S. Spaeter (*University of Strasbourg*), P. Saint-Raymond (*Conseil général des Mines*), F. Ménage (*Institut de radioprotection et de sûreté nucléaire*), R. Lahidji, M. Pappalardo (*Cour des comptes*), J. Percebois (*University of Montpellier*). At the time of the preliminary discussions, other experts agreed to share their knowledge with those in charge of this report. In now delivering this large format work, the authors hope that they have not only succeeded in gathering together assessments and recommendations intended for the authorities, as expected of the CAE, but also in providing a synthesis that can be used by all those, both observers and decision-makers, concerned with the three main risks studied herein.

Risk in General and Major Risks

The notion of risk appeared in the 15th century in the narrow context of maritime expeditions, where it long remained confined, before its rapid development during the probabilistic revolution of the 18th century, which enhanced it by an uncertainty calculation instrument that appeared to be universal in scope. It then began to spread, both into everyday thinking, where its influence became pervasive, and in learned discourse, where it divided into various different branches according to the disciplines that made use of it. Engineers define risks connected with uncertain and harmful events by means of two data, i.e., a probability value for the occurrence of the event and a quantitative measure of the losses caused by the latter, while often proposing that the two numbers be multiplied by each other. For economists, –who elaborated their own tools–, this formula is only a special case of a more general rule, that of expected losses, which takes any given number of events into account and then adds multiplicative terms together, instead of considering them only one at a time. Since engineers came to take up this rule and its numerous refinements, the mathematical treatment of risk has become partly unified.

Legal theorists, on the other hand, appear to a large extent impervious to the quantification of risk, and their definition, an example of which is given below, sounds rather like a formalisation of everyday thinking: "possibility of a future event, either uncertain or of an indeterminate term, not exclusively dependent upon the will of the parties and liable to cause the loss of an object or any other prejudice" (*Vocabulaire juridique*, Cornu, 1987). However, current European law accords a place to engineers' methods and, under its influence, these are beginning to be included in regulations, or even in legal texts, under French law.

Finally, geographers and cartographers form another disciplinary group concerned with investigating risk, and natural risk in particular. For them, the notion of risk can be divided into three constituent elements. *Hazard* is an uncertain and harmful event, presumed to be wholly or partially independent of the will of humankind, as in the case of natural disasters; *stakes* (sometimes called *exposure*) refer to socioeconomic values –human lives, capital, environmental heritage, the turnover of businesses and the income of private individuals– liable to be damaged by an occurrence of the hazard; and finally, *vulnerability* determines the extent to which these values will actually be destroyed.

When they are expressed numerically, these notions can be arranged in the following manner:

$$\textit{Losses (or damage)} = \textit{stakes} \times \textit{vulnerability}$$
$$\textit{Risk} = \textit{hazard} \times \textit{losses} = \textit{hazard} \times (\textit{stakes} \times \textit{vulnerability})$$

One recognises the engineers' multiplicative formula, hazard corresponding to their probability, with their losses being now usefully broken down into a factor of maximum loss (stakes) and a percentage of actual destruction (vulnerability). Since the engineers' formula is a special case of that used by economists, it may be concluded that, with the exception of law and in spite of certain dissimilarities, the specialised fields of risk share a common analysis.

This observation facilitated the report's methodological choices: the authors thought it possible to make use of the economic theory of decision under risk without breaking with the considerable contributions of engineering and geography. In order to ensure proper compatibility with legal thought, they have chosen to avoid mathematical formalism and to give priority of expression to the concepts of hazard, stakes and vulnerability, which belong to common sense as much as to technical knowledge. Moreover, these concepts inform French official documents (see the guide published by the French Ministry for Sustainable Development, *La démarche française de prévention des risques majeurs* ["The French Approach to Major Risk Prevention"] in 2011) as well as foreign and international documents, a fact that in itself makes them highly relevant.

Once the general characteristics of risk are established, it remains to define the notion of a major risk. The report contents itself with defining it as a social risk of vast dimensions, which is measured, when the data so permits, by the mathematical expectation of losses (these being defined by the product of *stakes* x *vulnerability*). In practice, this criterion implies exposure of a large number of people, a consideration that also comes readily to mind. If the definition presents any conceptual difficulty, it is to be found in the way in which individual risks are to be separated from social risks, of which major risks appear as a subcategory. Indeed, authors such as Beck and Ewald have emphasised the characteristic tendency of contemporary societies towards the "socialisation of risks", which in fact covers a wide range of phenomena: the interlocking of individual activities means that each of the latter can be a potential cause of risk to others; an increasing proportion of risks are covered collectively by means of private insurance or the welfare state; while guarding against old risks, society gives rise to new ones, which can be even more serious; taking care of risks before and after the occurrence of hazards is becoming a major social activity; risk-sharing comes into the field of political debate no less that the distribution of wealth. While giving due consideration to these ideas, the report does not attempt to take them further, but relies upon an intuitive definition of social risks, within which major risks are simply distinguished by their particular seriousness.

The preliminaries of the report conclude by classifying the responses likely to be made to such risks by public initiative:

- *ex ante* measures, that is to say measures taken prior to the occurrence of the hazard. These include recognition of the risk and technical and scientific assessment thereof, monitoring of advanced indicators, provision of information to the parties concerned, if necessary supplemented by public debate, and finally, preventive measures;
- *interim* measures, which are situated after the occurrence of the hazard, but before all of its consequences have ensued, consist of crisis management and mitigation of initial damage;
- *ex post* measures, that is to say measures taken after the occurrence and after full assessment of the damage, are concerned with material and financial compensation for the latter, to which is added learning from experience in order to inform subsequent *ex ante* measures;
- *combined* measures, which are so defined because they are taken *ex ante*, but have rigid *ex post* effects, consist of instituting insurance or rules of civil liability which determine the transfers to be made in case the hazard occurs.

In economic terms, discretionary compensation, as allocated by the State after disasters, differs from insurance compensation of the same value, from which it can be seen that *ex post* measures are distinct from what are here referred to as combined measures. Moreover, these measures differ from prevention and other *ex ante* actions because of the non-fortuitous nature of the effects that they are intended to produce.

Exposure to Major Risks in France

The report now returns to the three groups of major risks, recalling their physicochemical mechanisms if need be, and providing a sample of the available maps in each case. The presentation is ordered by means of the categories of hazard, stakes and vulnerability. Considering the three components of risk, rather than the hazard component alone, makes it possible to determine the level of risk in a given territory, and maps would entirely fulfil their role if they depicted these three components simultaneously.

Exposure to Natural Risks

The French Ministry for Sustainable Development has established the following list of high-risk natural phenomena:

- floods (main cases: river floods, surface runoff, groundwater level rises, coastal floods);
- ground movements (main cases: sinking, subsidence, landslips, landslides, shrinking coastlines, differential settlement);
- earthquakes;
- avalanches;
- volcanic eruptions;
- forest fires;
- phenomena linked to atmospheric conditions (main cases: cyclones, storms, hail and snow).

When one of these hazards occurs, its consequences do not always have the level of seriousness that defines a major risk. On the basis of this criterion, the report highlights three natural phenomena: *floods*, on the one hand, *differential settlement*, on the other, and finally *cyclones* and *storms*. Differential settlement is also designated –more clearly– as *expansion and contraction of clays*: by expanding or contracting, clays can move the earth below buildings by several centimetres, sometimes with serious effects upon walls and foundations. The great summer droughts contribute to this phenomenon, which occurred on an unusual scale during the heat wave year 2003.

The national territory is particularly exposed to the risk of flooding, which, from the point of view of hazard, is explained by the geography of Metropolitan France, subject to heavy oceanic rainfall and traversed by vast drainage basins. From the point of view of stakes, the risk arises from the traditional concentration of human beings and human activities alongside rivers and coasts. Vulnerability depends upon preventive facilities –which have grown in number at the initiative of the State since the 19th century–, as well as, quite naturally, upon the distribution and quality of buildings; and yet in both of these respects, much is left to be desired. When all is said and done, close to half of France's municipalities remain exposed. The land area at risk of frequent flooding is assessed by the International Office for Water (*Office international de l'eau*) at between 5 and 7% of the territory of Metropolitan France, excluding surface runoff. The French Ministry for Sustainable Development is pursuing a vast hazard-mapping project, which is still far from being exhaustive, even for the part of the territory that is most at risk.

In order of territorial impact, differential settlement occurs immediately after floods. Whether the hazard is present depends both upon the clayey nature of the subsoil and local variations in temperature. The stakes involve exclusively buildings, and individual houses are more fragile than apartment buildings; thus scattered urbanisation and the growth in the number of second homes contribute to vulnerability. To a greater or lesser extent, Metropolitan France has a 60% level of exposure, with

the Paris Basin, the Aquitaine Basin, the department of Puy-de-Dôme, the Moselle valley and certain parts of the North and South East of the country being especially affected. Mapping of the hazard is in progress; this should be on a large-scale, since it is not even uniform on the territory of a given municipality.

The two previous risks also stand out from the others by virtue of their economic importance. In absolute terms, they account for both the largest number of "natural disaster claims" ascertained for the 1995-2005 period (respectively 501,000 and 231,000 out of a total of 778,000) and the highest associated costs (4.68 and 3.53 billion euros respectively). However, comparisons are distorted by this data since French law restricts the definition of natural disasters, especially by discarding most phenomena connected with the atmosphere. In this respect, only cyclones occurring in French overseas departments and territories are counted (as defined by the wind force over a certain period); and yet the storms that occur in Metropolitan France can be economically disastrous. Those of 1999, the Lothar and Martin cyclones, caused 6.9 billion euros of compensated damages (data from the *Fédération française des sociétés d'assurance* ["French Federation of Insurance Companies"] for 2009). For its part, cyclone Xynthia of February-March 2010 resulted in more than 400,000 claims totalling 1.5 billion euros paid by insurers (current estimate by the same body). Total damages exceed these amounts, which places cyclone and storm risks at the same level as those for flooding, and much higher than differential settlement risks.

Exposure to Technological Risks

In the absence of convenient data from geographers and engineers, the report has chosen to rely directly upon an official category, that of "installations listed for reasons of protection of the environment" (ICPE / *installation classée pour la protection de l'environnement*). The category originates in French law, its main source being an act of 1976, although it is henceforth clearly in line with European law, the major sources of the latter being the three so-called Seveso directives (1982, 1996 and 2012). The various types of ICPE are fixed by means of a nomenclature established by the French Council of State (*Conseil d'Etat*): some are listed because of the *substances* handled or stored (toxic, explosive, combustive, etc.), while the others are included because of the main *activities* conducted (all branches of industry and agriculture include such activities). Both the distinction and the nomenclature in general lack a sound conceptual basis, though the latter corresponds to the practical requirements of the administration and, in particular, to those of the specialised inspectors who supervise the establishments in which ICPEs are found.

ICPEs are divided by the nomenclature into three administrative categories according to the seriousness of the danger that they present, as measured by certain quantitative levels. The least dangerous ICPEs require no more than a declaration on the part of their operators; for the other categories, however, the operators are obliged to apply for authorisation, the granting of which may involve public easement for the control of urbanisation. There is also a registration procedure, of recent date, which is intermediate between the previous two. European law has complicated this structure by introducing the notion of *Seveso establishments*, which the French law has made compatible with the nomenclature as follows: the "upper-tier Seveso establishment" category is identified with that of ICPEs subject to authorisation and public easement, while "lower-tier Seveso establishments" are placed in the much wider category of ICPEs subject to simple authorisation. The consistency of the ideas is not thereby improved, since the concept of 'establishment' (favoured by European directives) does not coincide with that of 'installation' (favoured by French laws).

According to data collected from the ICPE inspectorate, 500,000 establishments comprise ICPEs, of which 45,000 are subject to authorisation. There are maps to locate hazards in the form of Seveso establishments at least; a cursory view of exposed stakes can then be gained by superimposing a map of population densities. This graphical representation brings the scale of the technological risk to light, while also explaining it: companies set up in the same areas in which the general population resides, typically along transport links and close to commercial markets and labour pools, and these two phenomena of spatial polarisation reinforce each other.

Exposure to Nuclear Risk

In order to deal with exposure to nuclear risks, the report only takes *power plant accidents* into account, while excluding two other cases: non-accidental exposure to radioactivity, for example on the part of medical staff, and that of populations to fuel and fissile waste on the occasion of transport or storage.

France currently has 12 decommissioned nuclear reactors, 58 working reactors divided between 19 nuclear power plants, and one reactor at the construction stage. Of these, the first group is composed of obsolete UNGG (*Uranium Naturel Graphite Gaz*) type of gas-cooled reactors, and the second group of generation II type of pressurized water reactors (PWR), which were brought into operation from the nineteen-seventies. Over the years, these power plants have been subject to progressive technical advances based on information collected from throughout the world, including the experience gained from the celebrated disasters. The EPR (European Pressurized Water Reactor) currently being built at Flamanville represents generation III, which will have the advantage of reinforced safety.

Engineers distinguish three functions essential to the safety of a power station: cooling of the reactor core, control of the nuclear chain reaction and containment of radioactive products. They devise hypothetical accident scenarios on the basis of failures in one or several of these functions, and rely for this task on causal analyses that are most of the time purely determinist in character. The preventive measures put in place as a result of these assessments are aimed at meeting the objective of *defence in depth* of the power station, which is at the heart of the French safety doctrine. As in military organisation, the lines of defence come into operation one after the other, only being activated if the previous lines have been overcome. Each line consists of a specific set of material components and working procedures, both for normal functioning and exceptional circumstances, which should be enough to guard against accidents of the class considered. The strength of a defensive line is expressed in terms of safety margins, that is to say maximum tolerable deviations as compared with expected operation. Thus safety improvements are made either by adding new defensive lines, or more commonly, by increasing margins, the number of defensive lines remaining equal.

The report stresses the French safety doctrine's particular characteristic of leaving very little room for probabilistic reasoning. *Probabilistic risk assessments* emerged in the nineteen-nineties under the influence of American research and remain limited in their object (only concerning internal fault breakdowns); moreover they still need to be articulated with defence in depth. As it is currently conceived of, defence in depth is aimed at no less than a zero or negligible risk, given present knowledge. Whatever view is taken of this conception, it cannot be criticised for being static, since it uses feedback from experience as a basis for constant improvements. Thus the cost of the additional safety measures occasioned for EDF (*Electricité de France*) by the Fukushima disaster is expected to come to between 8 and 12 billion euros.

The nuclear risk to which the territory is subject is easy to describe as far as hazard is concerned, but eludes more subtle analysis aimed at taking the stakes and vulnerability into account. Damage estimates come to 60 billion in case of a serious accident, such as that of Three Mile Island, and between 600 and 1,000 billion in the case of a disaster, such as those of Chernobyl and Fukushima. These figures, which were announced by the French Nuclear Safety Authority (ASN, *Autorité de sûreté nucléaire*) and the French Court of Accounts (*Cour des comptes*) in 2012, are drawn from a single study produced by the French Radiation Protection and Nuclear Safety Institute (IRSN / *Institut de radioprotection et de sûreté nucléaire*), and are difficult to use in their present state. The mapping of nuclear risk is no more elaborate than that of technological risk. It amounts to combining the map of basic nuclear installations –among which power stations– with that of population densities, and adding concentric circles in order to represent radioactive diffusion.

Public Initiative with regard to Major Risks

Having described the forms of public initiative in section 1, the report now examines the content thereof, in terms of law and administrative practices with regard to major risks. As far as *ex ante* measures are concerned, it deals above all with assessment and prevention, laying particular stress upon combined *ex ante* and *ex post* measures (insurance and liability), which are well suited to analytical treatment. Other measures are only considered occasionally. Before going into these matters, the report takes a chronological look at the legal mechanisms that provide a framework for public initiative.

Background Legal and Institutional History

A legal and regulatory framework applicable to major risks started to emerge in the 19th century partly –but only partly– in response to the occurrence of disasters. The imperial decree of 1810, which a persistent legend associates with the far earlier explosion of the Grenelle gunpowder factory, sets out the principles of distance, control and authorisation of industrial activities, which were to remain permanent considerations. Current law on ICPEs remotely stems from this decree and a further act passed in 1917. Similarly, the act of 1858, prompted by disastrous rises in the levels of the Loire and the Rhone, paved the way to a policy of prevention through the construction of dykes and even at that early date, by means of mapping and zoning.

In the course of the 20th century public initiative extended its scope with regard to both of these classes of risk, eventually covering all of the forms of action described above. It henceforth takes place within a relatively consistent framework of organised regulatory schemes. The cornerstones of this unification are the aforementioned act of 1976, which instituted the ICPEs, and the act of 1982 concerning compensation of natural disasters, which deals with them by means of a mix of private insurance and state intervention, taking an innovative mixed economy approach.

Both of these systems were perfected by subsequent laws which, up to a certain point, also brought them closer together. A decree of 1977 provides that all ICPE authorisation applications have to be accompanied with safety reports; this requirement was maintained while the rules for completing the safety reports became more technical (to the point that they now come close to using probabilistic methods). A fund for the prevention of major natural risks, and above all, the *plans for the prevention of natural risks* (PPRN / *plans de prévention des risques naturels*), which have become the essential tool of public initiative, were instituted by the 1995 act referred to as the 'Barnier' act. These plans were then adapted to the other class of risk in the form of *plans for the prevention of technological risks* (PPRT / *plans de prévention des risques technologiques*) by the 2003 act referred to as the 'Bachelot' act, which also brought the systems closer together by putting in place technological disasters insurance. The new scheme was inspired by natural disasters insurance, while being developed less extensively than the latter.

At the same time, the ORSEC plans (French civil security plans in case of disaster) and crisis management rules were being reorganised by acts on civil security, putting in place the special emergency response plans (*plans particuliers d'intervention*). Such plans not only prepare immediate action, but are preventive in nature (like safety reports, they are concerned with given structures and establishments rather than territories). Later statutory texts fixed the principles of zoning around exposed sites, a normative procedure which was to lead to inevitable disputes with local elected representatives, who have had the authority to issue building permits since the decentralisation acts of 1982-1983.

In recent years, several European texts have been transposed into French law. Among these, one of the most important is the 2007 directive concerning floods, which obliges France to establish flood risk management plans at the level of hydrographic districts, before 2015. Moreover, cyclone Xynthia served to reveal a large number of costly problems, which stimulated new desire for reform. At La Roche-sur-Yon in March 2012, the President of the French Republic declared that "nothing can be left unchanged with regard to the prevention of natural disasters". This commitment marked the beginning of an administrative and legislative process: in May 2012, the government lodged a *bill instituting a reform of insurance cover for natural disasters* before the Senate. This document, along with the accompanying impact study, is an essential reference, and the following section draws a parallel between it and the report's recommendations.

As compared with natural and technological risks, nuclear risks are distinguished by the fact that they are principally governed by forms of law originating from the executive rather than the legislature (*règlement* versus *loi* in French

legal terms). In the history of the 5th French Republic, nuclear risk was in fact long exclusively confined to the executive sphere. The legal framework put in place around the Messmer plan of 1974 placed risk assessment and control under the responsibility of the nuclear industry, which at that time actually meant the State, since the latter was the owner and manager thereof. Such centralised organisation would be incomprehensible were it not associated with the objective of national independence, linking civil nuclear energy, responsible for ensuring adequate levels of energy supply, with military nuclear energy, the guarantor of diplomatic sovereignty.

This mode of organisation was overtaken by geopolitical transformations and changes in mentalities. The turning point can be traced back to the Chernobyl disaster, from which the radioactive fallout on the national territory was poorly assessed and, moreover, partly concealed. It marks the arrival on the scene of Parliament, which began to play a greater role, as well as that of groups, associations, and media reflecting public opinion, which were also destined to become important actors. The main law in this area is the 2006 act on openness and nuclear safety (referred to as the TSN "*transparence et sûreté nucléaire*" act), which created the ASN, investing it with the status of an independent government agency with specific regulatory powers (*autorité administrative indépendante*). The IRSN had been created by decree shortly before the latter act, with the assessment of nuclear and radiological risks having been declared its exclusive responsibility. Through the creation of these two bodies, along with related changes in the status of EDF and Areva (i.e., the largest French company involved in the development of nuclear power plants), the various components of nuclear safety in France finally gained their autonomy, with regard to the central administration as well as in relation to each other.

Assessment and Prevention Measures with regard to Natural and Technological Major Risks

The way in which major risks are assessed was outlined in section 1, which also specified the report's technical sources. The Gaspar database and the multifunctional *Cartorisques* software are the two major sources as far as natural risks are concerned. These are knowledge-based tools without regulatory significance, unlike plans for the prevention of natural risks (PPRN) and other preventive documents, whose information must be treated with caution, owing to the fact that they are derived from a form of negotiation between the parties involved (prefects, local elected representatives, decentralized departments of ministries, businesses and, in some cases, private associations). Whatever the sources, it is noticeable that they provide much more information on the hazard than on the stakes and vulnerability. Technological risks, for their part, are even more difficult to assess fully, both because they are more diffuse, in view of the large number of ICPEs, and because purely knowledge-based tools are lacking. Safety reports are the major source here; yet these are only concerned with one establishment at a time, and owing to the fact that they are issued by the companies concerned, they reflect the latter's individual choices, although the administration manages to impose a certain unity upon such reports.

Preventive measures are dependent upon technical factors specific to the hazard and stakes considered and do not therefore lend themselves to interesting comments of a general nature. The report brings out some salient characteristics of flood prevention. Prevention of this hazard is traditionally organised by means of containment structures built around rivers subject to rises in water levels. However, current policy, in particular since the major river plans (*plans grands fleuves*) of the nineteen-nineties, is to extend containment to the drainage basin as a whole. Structures are thus built around tributaries and, even more importantly, rises in river levels are often accepted as inevitable, with flood control basins provided for this purpose. Indeed, alongside dams and flood barriers, the latest work aimed at protecting the Île-de-France region involves rehabilitating the flood plains of La Bassée, at the confluence of the Seine and the Yonne. Unfortunately, new directions often remain programmatic, and the work in the Île-de-France is still at the preliminary design stage, although studies began during the 2000s.

Reduction of vulnerability to flooding is no less essential than flood prevention, and requires control of urban planning. Practical adjustments to constructions will play a role, as they have always done, and it makes sense to defend the transport and network infrastructures, however such minor measures cannot act as a substitute for *a policy aimed at freeing from constructions those zones which are subject to serious and recurrent flooding*. The PPRN do not properly play their preventive role, for the same reasons that made them questionable with regard to risk assessment. The French Court of Accounts showed the defects of the system after cyclone Xynthia in 2010 and the subsequent floods in the Var department, and its findings are corroborated by evidence provided to the authors of this report by technical departments.

Thus, as far as flooding is concerned, preventive efficacy does not measure up to the considerable resources allocated by the authorities. It is to be feared that public initiative, coming up against obstacles in matters of vulnerability, would become unbalanced in seeking increasingly costly, if well-inspired measures for reducing hazard. Since budgetary constraints will prevent the completion of such measures within acceptable deadlines, preventive policy is far more uncertain than official assessments might suggest.

Compensation and Insurance with regard to Natural Risks

The report expands at length upon the natural disasters compensation scheme, both for its intrinsic interest and because reforming it is now a topic of discussion. It is in between compulsory insurance and optional insurance; no obligation is incumbent upon parties –whether private persons or corporations– that refrain from taking out insurance against damage to property, however, those that do take out such insurance are obliged to take out additional insurance cover for natural disasters, which the insurer is bound to provide for them. This extra coverage gives rise to an extra premium, which is based upon the basic contractual premium with a standard rate throughout the territory (that is to say 12% on comprehensive household or business insurance, and 6% on motor insurance for land vehicles). By making the extra premium uniform, on top of imposing the preceding obligation, lawmakers intended to call upon national solidarity. Since the basic contracts are widely taken out, the majority of citizens contribute to providing compensation for damage claims, and what they pay can be presumed to grow with their wealth (the value of the property insured being a rough index thereof).

The theoretical argument for solidarity lies in the unequal distribution of natural disasters in both time and space, a feature that supposedly makes them *uninsurable by the companies* (or, at least, only insurable by the latter in consideration of exorbitant premiums). Today's Insurance Code does mention the non-insurability criterion, unlike the initial act of 1982. Indeed its role only became obvious as a result of subsequent practice. More specifically, it was established on the basis of legal precedent by the commission in charge of rulings on declarations of natural disasters (this inter-ministerial commission, which is chaired by a representative of the Interior Ministry, considers applications from municipalities claiming to have been affected by disasters). Thanks to this criterion, the authorities were able to limit the proclivity towards extending the system, and they have balanced the demands of victims of natural phenomena, who are always prompt to take advantage of a disaster, with those of insurers, who prefer to keep certain risks within their basic contracts. Budgetary constraints, linked to another feature of the scheme explained below, also played a restrictive role. The most significant change was to include the expansion and contraction of clays in the scheme in 1989, following the exceptional droughts of the time. Since then, the boundary of natural disasters with ordinary natural hazards has remained stable, and in particular, despite some pressures, fires as well as storm, hail and snow still belong to the latter class.

The last fundamental principle of the scheme holds that it should be supported by the State, though in an indirect manner. Its influence is exerted via the Central Reinsurance Fund (CCR / *Caisse centrale de réassurance*), a stock corporation (*société anonyme*), of which it is the 100% shareholder. Thanks to a special convention that provides it a State guarantee, this body offers advantageous reinsurance contracts to private insurers. CCR can ask for financial intervention on the part of the State whenever 90% of the equalisation reserves and special provisions that it has built up for natural disasters are needed to indemnify a year of claims. Insurers are legally entitled to turn to reinsurance companies other than CCR, but in practice rarely do so. As the latter is in effective contact with them, while being linked to the authorities, it appears to be the cornerstone of the natural disasters compensation scheme.

Taken as a whole, these characteristics make the scheme a *textbook model of mixed economy*. The 1982 lawmakers, and in particular rapporteur Alain Richard, had expressly envisaged it as such. They pointed out that collaboration between the public and private sectors would be more fruitful than either complete *laissez-faire* (deemed inadequate because of the scale of the risk) or purely public initiative (to which priority was initially given, in the form of a dedicated compensation fund, before being rejected as too costly). Criticisms levelled against the scheme amount to denying that this is a relevant mix, on the grounds that it fully achieves neither redistribution (subsidies financed by taxes would go further) nor efficiency of allocation (the insurance market left to itself would prompt better incentives). It can be objected to those who support these criticisms by economic analysis that such a tool cannot be applied mechanically, since the scheme should be assessed in terms of second-best, rather than first-best optimality. In less theoretical terms, that is to say that it is intended to establish a compromise between conflicting demands, which is enough to explain why none of the latter are entirely fulfilled.

While defending the intellectual principles of the natural disasters compensation scheme, the report emphasises certain shortcomings in its operation, and this leads the following section to propose reforming it. A very brief summary of the inadequacies to be considered is given below:

- the criterion of insurability lacks theoretical soundness and is not clearly explained. It seems to have been used in a somewhat opportunistic manner in the past, sometimes in order to extend the scheme's boundaries (by including the contraction and expansion of clays, which was questionable), and sometimes in order to reinforce them (by excluding storms in Metropolitan France, which was also questionable). This imprecision, however, should be weighed against the practical advantages of constructing the criterion via legal precedent in the inter-ministerial commission;
- the scheme does not actively encourage prevention, which is in principle one of the main reasons for choosing an insurance system rather than *ex post* compensation. Two factors contribute to this situation: the legal uniformity of the extra premium and, in practice, that of the basic premium (although insurers are entitled to adjust the latter to ascertained risks, they rarely do so). The system currently lacks any *price incentive*, and since absolute values are very small at least for the extra premium (on average, 17 euros for private individuals and 138 euros for businesses), the scheme leaves room for introducing such an incentive without breaking with the solidarity principle. This is not a new argument, and it has already led the authorities to refine the insurance scheme with a differentiated excess mechanism. When several natural disasters are officially declared with regard to the same municipality, and this municipality still lacks a plan for the prevention of natural risks, the applicable excess for the compensation of its inhabitants will increase with the number of official declarations. However, this mechanism has failed to exert its intended influence, so the scheme's incentive problem –its real Achilles' heel– needs to be reconsidered again.
- the financial balance of the scheme is also open to question. It relies upon the State guarantee accorded to CCR, enabling the latter to offer attractive contracts, which ultimately is reflected in the low level of extra premiums. All parties –not only the insured, but also the insurers, the reinsurer and the State itself– benefit from the guarantee as long as it is not called upon, but if it were to be thus called upon, the budgetary burden could prove insuperable. Admittedly, CCR has only implemented the guarantee on one occasion (in 2000, for 263 million euros, following the floods of 1999), but it has come close to doing so on another occasion (in 2003, in order to face up to the hazard of contraction and expansion of clays), and the historical trends testify to an increase in the number of natural disasters, under the influence of global warming and for other reasons mentioned in section 2. The scheme's virtuous behaviour in the past does not therefore predetermine what will become of it in the future. *These financial considerations tend to show, as do the preceding incentive-based arguments, that it has perhaps become imbalanced in favour of solidarity, at the expense of actual insurance;*
- the scheme has been weakened by the persistence of a large number of *ex post* transfers. An old doctrine holds that the State should be its own insurer. Under its influence, and also because the market would not always meet demand, only part of the property of the central State and regional authorities is insured. In such cases

compensation is based upon *ex post* transfers. With less justification, the central State and regional authorities have no qualms about offering *ex post* aid to the victims of natural disasters, even when they are insured and the scheme has played its role. The French Court of Accounts complained about the redistributive waste that followed the events of the year 2010. In this case the objection is not against the scheme, but against the authorities, which weaken it by juxtaposing a system in conflict with its very objectives of insurance and prevention.

Compensation and Insurance with regard to Technological Risks

Compensation with regard to technological risks falls within the operator's private liability, by contradistinction with compensation of natural risks, where this does not apply. According to a firm orientation of French law, the presence of a dangerous or harmful establishment is not a sufficient reason for inhabitants to desert their neighbourhood, and it is incumbent upon operators to endorse all of the consequences of their activity, up to the point –in some extreme cases– to leave the area. It makes no difference whether the inhabitants were present from the beginning, or on the contrary, moved in after the operator. In case of accident, the operator is therefore fully liable, and this liability is further increased when the courts understand it to mean strict liability (i.e. liability without fault).

Because of the enormous responsibility imposed upon operators, their ability to provide compensation for damage is sometimes uncertain, and lawmakers tried to remedy this state of affairs. At first sight, three means of action are open to the authorities: they can either directly contribute to the compensation, compel or encourage operators to remain solvent, or organise insurance cover against default on the part of operators, for the benefit of the victims. The first solution was rejected as being unfair to the taxpayer, the second was not considered, and the legislature opted for the third by creating a technological disasters compensation scheme. This is not intended as a substitute for the industrialist's responsibility, but only to guard against his insolvency or non-identification, as well as bringing the compensation forward while the legal proceedings follow their course. The scheme is partially modelled on that for natural disasters. All insurance contracts for damage to property taken out by private individuals are accompanied with an additional compulsory contract, which requires an official declaration of technological disaster in order to come into effect. The extra premium is unrestricted, though in practice very small. Unlike in the other scheme, the State does not provide its guarantee. As a further comparison, the connection between each scheme and its corresponding prevention plan –PPRN or PPRT– is closer in the case of natural disasters than of technological disasters.

The scheme appears to be well-designed, despite the fact that it has so far hardly been put to test, and if it were to deserve criticism in any respect, it would probably be for the excessive modesty of its ambitions.

The Nuclear Risk Insurance Scheme

Among the various forms of public initiative concerned with nuclear risk, only insurance still continues to fall within the scope of provisions dating from the earliest period of industrial use of the atom. The specific regime of civil liability on which these provisions are based also remains current. The Paris Convention on Third Party Liability in the Field of Nuclear Energy, signed in 1960, makes liability incumbent upon the operators alone for damage resulting from accidents occurring in their installations or connected with them (such as transport accidents). Consistently with the choice of "channelling" liability, the Convention adopted an interpretation of the latter as *liability without fault*, and created a liability ceiling as well as an insurance obligation up to this limit, thus following legal practice in cases where this interpretation of liability is used. Signatory States become liable beyond this ceiling, which they are entitled to increase. The Brussels Supplementary Convention of 1963 introduced a system of three tiers instead of two: the first, which is under the ceiling, is incumbent upon the operator, the second upon the national State, the third upon the signatory States jointly and severally. In any case, responsibility is again incumbent upon the operator beyond the last tier (although in practice, according to its solvency, the national State would also be liable).

A protocol was recently introduced in order to update the financial amounts covered under the last system: 700 million euros for the first tier, 500 additional million for the second, and 300 additional million for the third. Regrettably, this protocol has still not been ratified, and because of the wait-and-see policy adopted by the States, it is to be feared that the tiers will long remain fixed at the old values, which are completely obsolete even in the scenario of a nuclear accident of moderate seriousness.

Conclusions and Recommendations

On the basis of the partial findings of the preceding sections, the last section sets out the overall conclusions with regard to public initiative. Each conclusion is accompanied with recommendations, of which only a brief summary is given here.

With regard to *risk assessment*, the report adopts a critical position. Natural risks are a time-honoured concern of the State, but the abundant means that it devotes to them are somewhat disorganized. Table 9 of the report shows that there are too many competing sources and methods to assess the same hazard. This results in official assessments that are heterogeneous, and in spite of everything incomplete, since certain parts of the territory still elude risk assessment. In addition, as has been pointed out, this exercise remains focused on hazard, at the expense of stakes and vulnerability. Its should finally result in exhaustive mapping, both in terms of territory and according to the three pertinent dimensions, but this is far from having been achieved, even in the case of the two best-studied natural risks, that is to say river and coastal floods, on the one hand, and contraction and expansion of clays, on the other. This conclusion appears all the more disappointing in that France possesses teams and facilities of an impressive technical level, with regard at once to the administration, to State operators and to the insurance and reinsurance sector.

Recommendations 1 and 2 are aimed at correcting inconsistencies in the assessment of natural risks through better mobilisation of existing resources. They also reflect a principle that has become traditional in State reform projects, that is to say the institutional separation between risk assessment and management. The tone is set by the current approach to

handling nuclear risks, since the establishment of the IRSN and ASN as independent authorities constitutes a favourable precedent, and the authors think it possible to apply it to other contexts. They therefore propose *creating a natural risks assessment centre within the environmental administration that would be clearly separate from the administrative authorities*. This centre would comprise a *central level* and a *regional level*, the latter coordinating the currently scattered work of surveying and mapping on the ground. It would also be led to evaluate preventive measures resulting from decisions made by the administrative authorities. At the same time, a *data sharing network* would be put in place between the centre and bodies taking part in risk assessment (Météo-France [the French national meteorological service], the BRGM [*Bureau de Recherche Géologique et Minière*, the French geological survey], CCR and the *Observatoire des risques naturels* [French Natural Risks Watchdog], etc.).

As has been pointed out, in comparison with natural risks, technological risks suffer from a certain lack of neutral knowledge: the available sources are safety reports, information on ICPEs collected by the ministry and plans for the prevention of technological risks (PPRT), and they actually fall within the province of risk management. Moreover, the sources in question are local by nature and thus do not immediately correspond to the need for a national or even regional assessment. Considerable work therefore remains to be undertaken in order to raise assessment of technological risks to the level that –in spite of its limits– the assessment of natural risks has already attained, and it will be possible to accomplish this work all the more effectively insofar as the same principles are applied. Accordingly, in *recommendations 3 and 4*, the authors propose *creating a technological risks assessment centre, which would be clearly separate from the administrative authorities*, comprising a *central level* and a *regional level*; the latter would also be responsible for assessing the actual situation with regard to preventive measures. As in the preceding recommendations, a *data-sharing network* would put the centre in contact with the relevant bodies (INERIS the "French national institute for the industrial environment and risks", BRGM, etc.) as well as the ICPE inspectorate, whose in-depth work would thus be put to advantage.

Although the assessment of nuclear risks may seem open to criticism, this is certainly not due to the knowledge-based resources placed at its disposal, since it has the benefit of scientific and technological expertise of a remarkable level, but for reasons that should be traced to the very principles of the French doctrine of safety. We have already seen that this doctrine hinges on a conception of defence in depth that aims at neutralising risk. However, this is an impossible ideal because defence in depth is really adapted to certain risks and not to others. The list of accidents to be taken into account gets longer after each disaster, and that of Fukushima was particularly revealing. It showed that unfavourable events can add up in a power station to the point that customary safety margins are massively exceeded, with all of the defensive lines being broken at a single blow (thus, the Japanese operator TEPCO had not foreseen the possibility of the emergency generators failing at the same time as the main power-generating systems). Following the Japanese accident, stress testing of the French power stations and supplementary safety assessments were conducted, and they have already affected the safety doctrine. However, it would be desirable to go further by according a full place to the probabilistic point of view. Since no serious accident has a negligible probability, it is important to weigh up this probability against its costs (as computed by expected value or some other rule). In *recommendations 5 and 6*, the authors propose *continuing to revise the nuclear safety doctrine in the probabilistic direction, extending probabilistic risk assessments (PRA) to events that are external to the power station as well as to a wider-ranging catalogue of accident scenarios, and finally working at a more satisfactory evaluation of the damage caused by major accidents.* Contrary to the preceding recommendations, these are not directly intended for the authorities, but for risk assessors and inspectors at the IRSN and ASN, and within the operators.

With regard to *risk prevention*, the report also adopts a critical position. It stressed that plans for the prevention of natural risks (PPRN) were the main instrument in the prevention of natural risks and set out their shortcomings. These are not only attributable to the unduly political manner in which they are applied, but also to certain limits inherent to their conception. PPRNs are first of all oriented towards protecting human lives, and only comprehend urban planning indirectly and incompletely. Beside being too tolerant as far as future buildings are concerned, they hardly pay any attention to existing developed sites, thus allowing a whole area of prevention to escape consideration (vulnerability is at issue here and is once again neglected). They also lack the benefit of economic calculations, which would compare the advantages of high-risk implantations with their costs in case of accident. Following this harsh diagnosis, *recommendation 7* is to undertake *an in-depth reform of plans for the prevention of flood risks* (PPRI / *plans de prévention des risques d'inondation*, a special case of PPRNs). With a 2015 deadline, this reform would follow the same pace as the –compulsory– application of the European Floods Directive. In the complementary *recommendation 8*, the authors propose *creating a major natural risks inspectorate within the environmental administration;* it would be in charge of verifying that PPRNs comply with the risk assessments produced by the independent body envisaged in recommendations 3 and 4, and that the required preventive measures have been properly followed up.

As far as technological risks are concerned, the ICPE inspectorate plays an essential preventive role that needs expanding, but its staff levels have stagnated since the now distant AZF disaster. In *recommendation 9*, the authors propose increasing *the ICPE inspectorate's staff levels, and correspondingly, its role*. It would be entrusted with taking an even more active part in the preparation of plans for the prevention of technological risks (PPRT) and checking that the preventive measures contained therein have indeed been implemented.

With regard to *the insurance of major risks*, the report offers both criticism and approval. It aims at supporting the current reform of the natural disasters insurance scheme and therefore sets out its recommendations in this field while making reference to the bill of May 2012 that had been mentioned in the preceding section without any comment.

The current definition of natural disasters is of the "unspecified danger" type (*à péril non dénommé*), i.e., it is based only upon abstract criteria. The bill means to replace it with a definition of the "specified danger" type (*à péril dénommé*), and thus rules that a list of hazards be fixed by

decree after consultation of the French Council of State. In spite of the acknowledged weaknesses of the criteria, the authors favour the current type of definition, at the price of making some minor changes to the legal text(*). Owing to its case law approach, the natural disasters commission is able to adjust to scientific and technical data much better than a definite list, even a revisable one, would ever do. Furthermore, the commission has been able to take budgetary constraints into account –in 2003 in particular–, whereas a list would open up rights to compensation irrespective of their actual cost. *Recommendation 10* therefore asserts that *the "unspecified danger" definition should be maintained* On the other hand, it endorses *two of the bill's useful innovations*: it denies the benefit of cover to those who build on land where building is prohibited by a PPRN, and it removes the obligation, incumbent upon insured parties whose property has been destroyed, to devote the insurance moneys to reconstruction on the same site.

The inadequacy of the preventive incentives is, as already stated, the scheme's Achilles' heel. In this respect, apart from one natural risk that it addresses in depth, that is to say the contraction and expansion of clays, the bill is lacking in boldness. It rules that insurance companies would be free to differentiate the extra premiums within certain limits (once again fixed by decree after consultation of the French Council of State), but it limits this provision to local authorities and businesses, from a certain amount of insured capital onwards. No change is made to the base on which the extra premium is calculated, and no attempt is made to adjust the insured parties' excess any further than the existing system so permits. *Recommendation 11* pushes the reform in these various directions. The authors request that *the companies could also differentiate private individuals' extra premiums, that insofar as possible they should use insured capital as the base for calculating extra premiums, and that insured parties' excess should be raised in municipalities where natural disasters have been officially recognised on numerous occasions, in cases where these municipalities do not possess an approved PPRN or have not carried out the preventive work required by their PPRN.*

The bill includes commendable innovations with regard to the contraction and expansion of clays. It intends to restrict the benefit of cover to damage that compromises the solidity of buildings, whereas the scheme strayed off course in the 2000s to the point of covering purely aesthetic damage. It is also aimed at safeguarding the scheme by bringing the builder's ten-year building warranty into play as much as possible. In *recommendation 12*, the authors endorse *the proposed exclusions of cover* and take up another of the bill's provisions, which consists of *according legal value to the zoning of contraction and expansion of clays, and making compulsory for all new buildings that either a ground survey be made, or default preventive measures be taken.*

Aid allocated *ex post* did not come within the scope of the bill, and another one would be needed in order to bring an end to, or at least strictly limit such practices. All insurance schemes come up against the problem of bad incentives –the moral hazard of economic theory– and natural disasters insurance is no exception, but as the report stresses, the aid in question makes the situation still worse. Ineffectiveness of allocation is coupled with sheer injustice, since the charity of the State and regional authorities is unevenly distributed depending upon the time and the place. The effects are most noticeable in French overseas departments and territories: the population is to a large extent inadequately insured and appears to anticipate compensatory intervention (economic literature speaks of a "charity hazard" in such cases). In *recommendation 13*, the authors therefore call for *a bill which would strictly limit redistribution conducted in parallel with the scheme*, while favouring incentive measures in overseas France to reach a higher insurance rate there.

The report has only made a single criticism of the technological disasters compensation scheme: its lack of ambition. In this case insurance is no doubt restricted by the liability of the operator, a cornerstone of civil law, but it appears possible and desirable to widen its scope while respecting this constraint. Businesses could also have the benefit of advance payment of compensation that the law reserves to private individuals, and compensation to the latter, which is currently limited to main homes, could now provide broader cover for property and even persons. The authors therefore devote *recommendation 14* to a *considered extension of the technological disasters compensation scheme*.

It is impossible to foresee the amounts and terms of the compensation that would result from a nuclear accident of disastrous (like Chernobyl or Fukushima) or even simply serious proportions (like Three Mile Island). However, public finances would undoubtedly be called upon in unprecedented amounts, the State playing its role of insurer of last resort. In *recommendation 15*, by way of a palliative measure, the authors propose either *increasing the liability ceiling for industrialists in the nuclear sector* –without waiting for ratification of the new international insurance scheme– or alternatively *creating a reserve fund financed by the industrialists for the purpose of covering a part of the cost of an accident.*

(*) The Insurance Code (*Code des Assurances*) states that: "The purpose of this insurance is to guarantee financial compensation to the insured party for uninsurable direct material damage to the whole of the property covered by the contract, of which the decisive cause was the unusual force of a natural agent, when the usual measures taken in order to prevent this damage could not prevent its occurrence or could not be taken" (*chapter V, article appendix I art. A-125-1*). It is recommended that "unusual force" should bear on the damage caused by the natural agent rather than the agent itself.