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An Economic Analysis Of The Nuclear Liability Subsidy

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I. INTRODUCTION[1]

Energy markets are undergoing major change. They have to cope with a new economic environment and, at the same time, a new energy context. Indeed, on the one hand, energy markets are undergoing deregulation with the aim of opening them to competition.[2] They are also submitted to privatisation policies, which progressively detach them from the government's hold.[3] This trend is transforming the market structure and might particularly modify operators' behaviour and strategies. On the other hand, energy markets face new environmental constraints. Indeed, fossil fuel resources, such as oil, coal, and gas, which are still widely used today, are highly polluting and largely contribute to the greenhouse effect.[4] Moreover, they are getting scarcer and scarcer because their world reserves are running short.[5] Therefore, under the Kyoto Protocol regime, the question of future energy sources arises with acuteness today.

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1. We are grateful to the participants of the annual conference of the European Association for Law and Economics (EALE) (Madrid, Sept. 2006) for their useful comments on an earlier draft.

2. *See, e.g.*, Matthew W. White, *Power Struggles: Explaining Deregulatory Reforms in Electricity Markets*, 1996 BROOKINGS PAPERS ON ECON. ACTIVITY, MICROECONOMICS 201, 201 (1996).

3. *See id.*

4. *See, e.g.*, Intergovernmental Panel on Climate Change, *Fourth Assessment Report*, 2007.

5. The exhaustion of the current world reserves for oil, gas, and coal are respectively estimated at 40 years, 70 years, and 230 years, at the current level of consumption. *See* Energie et environnement, http://www.cea.fr/jeunes/themes/l_energie/la_production_d_energie/energie_et_environnement (last visited Feb. 2, 2009).

In such a context, the role of nuclear energy in future energy policies is coming back on stage. Indeed, nuclear energy is considered to have great potential, especially under new environmental requirements related to the necessary reduction of CO_2 emissions.[6] It is abundant, immediately available and, most importantly, does not emit any greenhouse gases.[7] In this respect, it seems to be an ideal candidate for future energy programs which must focus on accessible, available, and carbon neutral energy sources. Thus, some countries are now discussing the reintroduction of nuclear energy even in cases where nuclear energy was being formally phased out (like in the Netherlands).[8] However, nuclear energy also has shown severe weaknesses; it produces hazardous radioactive wastes[9] and generates risks for extensive damage to the environment and public health.[10] If the problem of radioactive wastes management already has some (even sub-optimal and still uncertain) solutions, the problem of nuclear risk management is far from being solved. Indeed, the nuclear risk management shows two complex dimensions. First, given the uncertainties involved and high aversion of the general public towards nuclear risk, a minimization of the risk is required through draconian safety rules. In this respect, the International Atomic Energy Agency (IAEA) and the NEA (Nuclear Energy Agency),[11] at the international level, the Nuclear Regulatory Commission (NRC), at the U.S. level, and the EURATOM / EAEC (European Atomic Energy Community), at the European level, exercise drastic control on operators' installations and require the application of very strict safety norms.[12] Regulations by these agencies aim

6. *See, e.g.*, International Atomic Energy Agency, *Nuclear Power for Greenhouse Gas Mitigation*, 2000.

7. *See id.*

8. *See Borssele Nuclear Plant Definitely Staying Open Until 2033*, NIS NEWS BULLETIN, Jan. 11, 2006, *available at* http://www.nisnews.nl/public/110106 _1.htm.

9. *See* World Nuclear Association, Waste Management, http://world-nuclear.org/ education/wast.htm (last visited Mar. 22, 2009).

10. *See, e.g.*, World Nuclear Association, Chernobyl Accident, http://world-nuclear.org/ info/chernobyl/inf07.html (last visited Mar. 22, 2009).

11. The NEA is a specialized agency of the Organization for Economic Cooperation and Development (OECD).

12. Of course, the norms are not only imposed at the international level by these agencies but also through national safety regulations. In certain cases, standards and recommendations are adopted jointly by the IAEA and other international organizations (not specifically "nuclear"), like the WHO (World Health Organization, Geneva), the ILO (International Labour Organization, Geneva), the FAO (Food and Agriculture Organization, Roma), and the ICRP (International Commission on Radiological Protection, a non-governmental organization, London). The international conventions currently in force on this subject are the IAEA Convention on Nuclear Safety and the IAEA Joint Convention on the Safety of

at avoiding, as far as possible, nuclear accidents *ex ante*.[13] Thus, nuclear risk management is primarily concerned with the tools that provide nuclear operators incentives to internalise the risk costs in order to maximize prevention. In addition, the international regime addresses the need to provide compensation to victims in case of accidents *ex post*.[14] The obligation to provide compensation to victims is also important in the light of the need to internalise costs. This point is crucial, especially if governments are reconsidering the role of nuclear energy in future energy policies. Indeed, since they generate risks for the environment and for human health, from an economic perspective, nuclear operators have to be exposed to the full risk costs that they generate. This means that efficient internalisation and compensation mechanisms have to be designed to cover these risks. In practice, internalisation means the integration in the operator's general costs, of the costs resulting from the external effects of his activity.[15] Many legal and economic tools (some of which result from international conventions) exist to reach such goals: in addition to the mentioned *ex ante* safety regulation aimed at prevention, compensation is addressed via civil liability rules and (partially) via the insurance market.[16] In addition, in some cases, there is government intervention in the compensation as well.[17] The implicit market rule for an operator who creates a risky activity is that he assumes all risks he generates through the internalisation of the resulting costs.[18] This rule of thumb sounds quite intuitive; however, nuclear operators, unexpectedly, do not seem to entirely follow it. Indeed, since the development of nuclear energy in the late 1950s, nuclear operators have benefited from a quite favourable liability regime that initially endeavoured to protect them and to allow the growth of nuclear industry. One can, however, question whether fifty years later, this justification is still relevant, particularly with regard to the negative effects

Spent Fuel Management and On the Safety of Radioactive Waste Management, both drafted in Vienna respectively on June 17, 1994 and on September 5, 1997.

13. *See, e.g.*, INST. OF NUCLEAR POWER OPERATIONS, PRINCIPLES FOR A STRONG NUCLEAR SAFETY CULTURE (Nov. 2004), *available at* http://www.nrc.gov/about-nrc/regulatory/enforcement/INPO_PrinciplesSafetyCulture.pdf.

14. *See, e.g.*, Michael Trebilcock & Ralf Winter, *The Economics of Nuclear Accident Law*, 17 INT'L REV. L. & ECON. 215 (1997).

15. *See, e.g.,* Reiner Friedrich & Alfred Voss, *External Costs of Energy Regulation*, 21 ENERGY POLICY 114 (Feb. 1993).

16. Stephen Shavell, *The Judgment Proof Problem*, INT'L REV' OF L' & ECON., 1986, at 43-58.

17. *See infra* Section II.

18. *See, e.g.*, Friedrich & Voss, *supra* note 15.

this legal regime induces in terms of incentives, compensation, and efficiency. Until now, the nuclear operators have, at the international level, always benefited from a strong political support and from important subsidies.[19] These subsidies are twofold. They are relative to: 1) their civil liability which is limited (and so are their corresponding insurance premiums); and 2) to the fact that the State takes over the remaining costs.[20] As a consequence, these subsidies produce strong distortions since they impede the complete internalisation of the risk costs by nuclear operators.[21] Even though this subsidy for the nuclear industry was also hard to justify from an economic perspective when the industry stood at the beginning of its development, there still was large political support (and probably public acceptance) given industrial optimism in the 1950s and the belief in the promise of this new energy source.[22] The political context today has, however, changed. Thus, in the current context of market deregulation, support by the state of the nuclear industry is no longer widespread.[23] Moreover, the limited compensation to victims may no longer be accepted either, given increased public awareness and general sensitivity towards the nuclear risks. Since the accidents at Three Mile Island and Chernobyl, the risk of a serious nuclear accident is no longer merely hypothetical.

Today, as far as the U.S. is concerned, the Price-Anderson Nuclear Industries Indemnity Act[24] has features that largely distinguish it from the international regime. Whereas initially the Price-Anderson Act consisted of a two-tier system whereby a small part was covered by the nuclear operator, and a much bigger part of total compensation was provided for by public funds, this has dramatically changed since its 1975 revision.[25] Currently, the total amount of compensation is financed through an individual liability of the operator and a second collective tier financed by all licensed American nuclear operators through so-called retrospective premiums (and thus

19. *See infra* Section II.

20. *See id.*

21. *See id.*

22. *See, e.g.*, President Dwight Eisenhower, Atoms for Peace, Speech Before the United Nations General Assembly (Dec. 8, 1953).

23. *See, e.g.*, Chris Hammer, *Coalition Goes Cool on Nuclear Energy Plants*, THE AGE, Feb. 28, 2008, *available at* http://www.theage.com.au/news/ environment/coalition-cools-on-nuclear-plants/2008/02/27/1203788442704.html.

24. Price-Anderson Act of 1957, 42 U.S.C. § 2210 (2006).

25. *See infra* Section II(A).

no longer through public funding).[26] The second subsidy effect (public funding) is hence, today, absent under the U.S. Price-Anderson Act.

In sum, reconsidering the role of nuclear energy in future world energy policies stands high on the political agenda today. This should equally lead to a renewal of the question of the nuclear operators' liability in case of accidents and of the possibility to provide adequate coverage of the risks either through insurance or through alternatives. Addressing such a question today is all the more relevant, since the Conventions that govern the nuclear operators' civil liability regime at the international level, have recently been reformed. In other words, it is necessary to re-examine the relevance of the current legal and economic mechanisms of internalisation and to revise the role of the State in this respect. In this paper, we analyse the reform of nuclear liability according to the international regime using an economic analysis of law. Although we will mainly focus on the international regime, we will briefly mention, mainly in comparison, the situation of the U.S. Price Anderson-Act as well.[27] Some legal and economic scholars have already analysed the efficiency of the international liability regime. In this respect, we notably build on the earlier work of Trebilcock and Winter[28] and Faure and Skogh.[29] We will use the economic analysis of law more particularly to address the compensation for victims of nuclear accidents in France. Focussing on one particular legal system has the advantage of analysing the subsidy and the available compensation to victims in a concrete manner. However, since French law, in this respect, is based on international conventions, our analysis clearly has implications for other legal systems with similar features as well.

26. *See* Omer F. Brown, II, "Legislative History of Government Indemnification Under the Price-Anderson Act", paper presented at *The Price-Anderson Contractors Policy Issues Study* 1–22 (Sept. 1984); *See also* Omer F. Brown, II, Nuclear Liability Coverage Developments in the United States of America, Speech given at the Association Internationale Du Droit Nucleaire/International Nuclear Law Association, Nuclear Inter Jura Rio de Jainero (1993).

27. The reason we are not providing a detailed economic analysis of the U.S. Price-Anderson Act is that it has been undertaken in previous research. *See* Michael G. Faure & Tom Van den Borre, *Compensating Nuclear Damage: A Comparative Economic Analysis of the US and International Liability Schemes*, 33 WM. & MARY ENVTL. L. & POL'Y REV. 219 (2008).

28. Trebilcock & Winter, *supra* note 14.

29. Michael Faure & Göran Skogh, *Compensation for Damages Caused by Nuclear Accidents: A Convention as Insurance*, 17 THE GENEVA PAPERS ON RISK AND INS. 499 (1992).

Our paper aims to accomplish two goals. First, we will provide and overview of how the legal regimes organize the subsidy to the nuclear operator.[30] Next, we will estimate the amount of the subsidy of the French nuclear operator. We also briefly discuss the calculations of the subsidy under the U.S. Price Anderson Act. This will permit us to corroborate our further arguments with empirical data.[31] Then, we will analyse the implications of the current legal regime in terms of incentives, compensation, efficiency, that is, in terms of internalisation of the risk costs. This will highlight the obvious distortions of such a regime.[32]

II. THE IMPLICIT SUBSIDY OF THE NUCLEAR OPERATOR

A. A Largely Favourable International Legal Regime

Implementing a legal liability regime for nuclear operators was perceived very early as a priority. Indeed, the first nuclearized countries rapidly understood the importance of setting up a legal framework to manage nuclear accidents from a prevention (*ex ante*) and compensation (*ex post*) viewpoint.[33] Hitherto, in many European States, the legislation relative to nuclear civil liability is governed by various international conventions.[34] The first one, the Paris Convention signed on July 29, 1960, was drafted within the framework of the NEA by the OECD.[35] Its formal goal was to provide adequate and fair compensation to victims of damages caused by nuclear accidents.[36] Ratified by fifteen European countries, it was then completed on January 31, 1963, by a second Convention, the Brussels Convention, which was ratified by twelve countries / parties to the Paris Convention.[37] A second regime came into being through the already mentioned UN-related IAEA. Within this framework, the Vienna Convention, relative to the civil liability for nuclear damages, was drafted and ratified on May 21, 1963, by thirty-two countries from South America, Eastern Europe, and

30. *See infra* Part II.

31. *See infra* Part III.

32. *See infra* Part IV.

33. *See, e.g.*, Convention on Third Party Liability in the Field of Nuclear Energy, July 29, 1960, 956 U.N.T.S. 251 [hereinafter Paris Convention].

34. *E.g.*, *id.*

35. *See id.*

36. Paris Convention, *supra* note 33, preamble.

37. Convention Supplementary to the 1960 Convention on Third Party Liability in the Field of Nuclear Energy, Jan. 31, 1963, 956 U.N.T.S. 265.

Asia.[38] Some States are party to the NEA regime, others to the Vienna Convention. A Common Protocol to all the Conventions was signed in 1988 after the Chernobyl accident to coordinate the scope of application of both Conventions.[39] These international treaties are implemented in the national laws of the signatory States. Within the limits set by the Conventions, the States benefit from autonomous room to manoeuvre.[40] In France, these Conventions are integrated in Law No.68-943, passed on October 30, 1968[41] (modified by Law No. 90-488 of June 16, 1990).[42]

Civil liability is a legal regime that, from an economic perspective, aims at internalising the costs of a damaging risk to third parties by inciting the potential actor to prevention. This is a standard insight of the economic analysis of law since the early works of Calabresi,[43] Brown,[44] and Shavell.[45] A basic notion is that the injurer should be fully exposed to damage costs in order to provide him with the necessary incentives for prevention.[46] In this respect, the current international legal regime of nuclear civil liability is, however, quite unsatisfying. Indeed, since the beginning of nuclearisation, the choice was made to implement a strict, channelled, and limited civil liability rule.[47] All of these characteristics of the liability regime have already been addressed from an economic perspective in the literature. The principle of strict liability holds liable the nuclear operator irrespective of his behaviour; there is no need for the victim to prove the fault or negli-

38. Vienna Convention on Civil Liability for Nuclear Damage, May 21, 1963, 1063 U.N.T.S. 265.

39. Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention, Sept. 21, 1988, IAEA doc. GOV/2326 Annex I, *reprinted in* 42 NUCLEAR L. BULL. 56 (1988).

40. Thus, States would be allowed to provide more compensation than the amounts laid down in the Conventions.

41. Law No. 68-943 of Oct. 30, 1968, Journal Officiel de la République Française [J.O.] [Official Gazette of France], Oct. 30, 1968.

42. Law No. 90-488 of June 16, 1990, Journal Officiel de la République Française [J.O.] [Official Gazette of France], June 16, 1990.

43. Guido Calabresi, *Some Thoughts on Risk Distribution and the Law of Torts*, 70 YALE L. J. 499 (1961); Guido Calabresi, THE COST OF ACCIDENTS: A LEGAL AND ECONOMIC ANALYSIS (1970).

44. J. P. Brown, *Toward an Economic theory of Liability*, 2 J. OF LEGAL STUD. 323.

45. Steven Shavell, *Damage Measures for Breach of Contract*, 11 BELL J. ECON. 466 (1980) [hereinafter Shavell, *Breach of Contract*]; Steven Shavell, *The Optimal Use of Nonmonetary Sanctions as a Deterrent*, 77 AM. ECON. REV. 584 (1987) [hereinafter Shavell, *Nonmonetary Sanctions*].

46. *See, e.g.*, Trebilcock & Winter, *supra* note 14.

47. *See, e.g.*, Paris Convention, *supra* note 33.

gence of the operator.[48] It is a quite common rule used to manage catastrophic risks.[49] The economic rationale is that in these so-called unilateral accident cases (where only one party, the operator, can influence the accident risk) only strict liability leads to a full internalisation of the accident risk.[50] This rule will indeed provide the operator not only with the incentive to follow optimal care but also to adopt an efficient activity level.[51] There is a requirement, however, that there is full solvency of the injurer or that the insolvency risk is in some way taken care of (e.g. by insurance).[52] Channelled liability means that the nuclear operator will be exclusively liable in case of accidents.[53] The formal justification for channelling is that it avoids the multiplication of procedures against constructors, suppliers or subcontractors and thus, makes lawsuits for victims easier.[54] This rule is, however, debatable from an economic perspective, more particularly since channelling excludes liability of others who could have contributed to the accident risk as well.[55] Finally, an element quite interesting for our analysis is the liability limitation. Indeed, in the international regime, the operator's nuclear civil liability is limited at two levels: in time and in amount.

48. *See* BLACK'S LAW DICTIONARY, *strict liability* (8th ed. 2004).

49. *See* M. A. de Figueiredo, D. M. Reiner & H. J. Herzog, *Framing the Long-Term In Situ Liability Issue for Geologic Carbon Storage in the United States,* 10 MITIGATION AND ADAPTATION STRATEGIES FOR GLOBAL CHANGE 647 (2005).

50. *See* Trebilcock & Winter, *supra* note 14, at 221-25.

51. *See* Shavell, *Breach of Contract*, *supra* note 45.

52. Stephen Shavell, *The Judgment Proof Problem*, INT'L REV' OF L' & ECON., 1986 at 43-58.

53. The only exceptions is the situation when the operator would be able to prove that the accident results from an intentional fault of one of his partners or when the damages are directly due to "an act of armed conflict, hostilities, civil war, insurrection or. . . a grave natural disaster of an exceptional character." Paris Convention, *supra* note 33, Art. 9; *see also id.* Art. 6(e).

54. *See, e.g.*, Michael G. Faure & Karine Fiore, *The Civil Liability of European Nuclear Operators: Which Coverage for the New 2004 Protocols? Evidence from France*, 8 INT'L ENVTL. AGREEMENTS: POL., L. & ECON. 227 (2008).

55. Ton Van den Borre, *Channelling of Liability: a Few Juridical and Economic Views on an Inadequate Legal Construction*, in CONTEMPORARY DEVELOPMENTS IN NUCLEAR ENERGY LAW: HARMONISING LEGISLATION IN CEEC/NIS 13-39; Michael Faure & Ton Hartlief, *Remedies for Expanding Liability*, 18 OXFORD J. OF LEGAL STUD. 681 (1998).

The time limit means that the victims must bring a suit for compensation against the nuclear operator within a prescription delay of thirty years after the accident in case of death or individual damages and within a prescription delay of ten years for other damages.[56] Through this first limit, the legislator estimated that beyond these delays, the causality link between the damage and the accident would be too hard to establish.[57]

The second liability limitation, the most relevant for our analysis, concerns the financial cap on liability. Indeed, in pursuance of the Conventions, the nuclear operator engages his civil liability in case of an accident only up to a certain amount.[58] This amount was first fixed by the Paris Convention in 1960, and has been modified many times since. For example, before the last modification Protocol of the Paris and Brussels Conventions,[59] the French operator's liability limit was fixed at € ninety-one million.[60] Now, this cap amounts to € 700 million[61] but this latest Protocol has not entered into force yet.[62]

56. *See* Paris Convention, *supra* note 33, Art. 8.

57. *See, e.g.,* Mark Tetley, *Revised Paris and Vienna Nuclear Liability Conventions – Challenges for Nuclear Insurers,* 77 NUCLEAR L. BULL. 27, 30 (2006).

58. *See* Paris Convention, *supra* note 33, art. 7.

59. The modification Protocol of the Paris and Brussels Convention on Nuclear Civil Liability was drafted on February 12, 2004, at the OECD head office, in Paris. *See* Protocol to Amend the Convention of 31 January 1963 Supplementary to the Paris Convention of 29 July 1960 on Third Party Liability in the Field of Nuclear Energy, as Amended by the Additional Protocol of 28 January 1964 and the Protocol of 16 November 1982, Feb. 12, 2004, *available at* http://www.nea.fr/html/law/brussels_supplementary_convention.pdf [hereinafter 2004 Protocol].

60. *See generally* Karine Fiore, *The Nuclear Liability Limit in the OECD Conventions: An Implicit Subsidy*, 2008, *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1086290.

61. *See* 2004 Protocol, *supra* note 59, art. 3(b)(i). This high increase of the liability cap might obviously have consequences in terms of internalisation. We will come back to this fact. *See infra* Section III.

62. According to article 20 of the Protocol, "[the new amendments] shall come into force when ratified, accepted or approved by two-thirds of the Contracting Parties. For each Contracting Party ratifying, accepting or approving thereafter, they shall come into force at the date of such ratification, acceptance or approval." 2004 Protocol, *supra* note 59, art. 20. The "reasonable delay" deadline to ratify the Protocol was fixed by the Council of the European Union at the December 31, 2006. *See* 2004 O.J. (L 097) 53.

Beyond this limit, the Brussels Convention provides a complementary mechanism of compensation based on public funds, for cases where the amounts fixed by the Paris Conventions would be insufficient.[63] For this matter, it adds two risk layers beyond the operator's liability limit. Indeed, at a national level, if the operator liability cap is not sufficient to compensate victims and to repair the damages of a nuclear accident, the State inside which the accident occurred must finance reparations up to a certain limit.[64] In French Nuclear Law, this limit is fixed at € 140 million.[65] Note that this second amount has also been increased by the last modification Protocol of the Paris and Brussels Conventions to € 500 million, but it has not entered into force yet.[66] At a supranational level, a third risk layer is enacted by the Conventions. If the operator's and State's financing are still insufficient, the States party to the Conventions must cover the exceeding damages up to € 150 million, on a solidarity basis.[67] The 2004 Protocol increased this limit to € 300 million.[68]

63. *See* Convention of 31st January 1963 Supplementary to the Paris Convention of 29th July 1960, as amended by the additional Protocol of 28th January 1964 and by the Protocol of 16th November 1982, art. 3, Jan. 31, 1963 [hereinafter Brussels Convention].

64. *See id.*

65. *See* Fiore, *supra* note 60, at 2.

66. *See* 2004 Protocol, *supra* note 59, art. 3(b)(ii).

67. *See* Fiore, *supra* note 60, at 2.

68. *See* 2004 Protocol, *supra* note 59, art. 3(b)(iii).

The respective coverage caps before[69] and after the 2004 amendments[70] are summed up in Table 1.

69. Before 2004, in the article 3 (a) & (b) of Brussels Convention, these different coverage caps are enacted as follows:

> (a) Under the conditions established by this Convention, the Contracting Parties undertake that compensation in respect of the damage referred to in Article 2 shall be provided up to the amount of 300 million Special Drawing Rights per incident; b) Such compensation shall be provided: i) up to an amount of at least 5 million Special Drawing Rights, out of funds provided by insurance or other financial security, such amount to be established by the legislation of the Contracting Party in whose territory the nuclear installation of the operator liable is situated; ii) between this amount and 175 million Special Drawing Rights, out of public funds to be made available by the Contracting Party in whose territory the nuclear installation of the operator liable is situated; iii) between 175 and 300 million Special Drawing Rights, out of public funds to be made available by the Contracting Parties according to the formula for contributions specified in Article 12.

Brussels Convention, *supra* note 63, art. 3(a)-(b).

70. The 2004 Protocol amended the article 3 (a) & (b) of the Brussels Convention as follows:

> (a) Under the conditions established by this Convention, the Contracting Parties undertake that compensation in respect of nuclear damage referred to in Article 2 shall be provided up to the amount of 1 500 million euro per nuclear incident, subject to the application of Article 12bis; b) Such compensation shall be provided as follows: i) up to an amount of at least 700 million euro, out of funds provided by insurance or other financial security or out of public funds provided pursuant to Article 10(c) of the Paris Convention, such amount to be established under the legislation of the Contracting Party in whose territory the nuclear installation of the operator liable is situated, and to be distributed, up to 700 million euro, in accordance with the Paris Convention; ii) between the amount referred to in paragraph (b)(i) of this Article and 1 200 million euro, out of public funds to be made available by the Contracting Party in whose territory the nuclear installation of the operator liable is situated; iii) between 1 200 million euro and 1 500 million euro, out of public funds to be made available by the Contracting Parties according to the formula for contributions referred to in Article 12, subject to such amount being increased in accordance with the mechanism referred to in Article 12 bis.

2004 Protocol, *supra* note 59, art. 3(a)-(b).

	Paris (1960) and Brussels Conventions (1963) (French Example)	Modification Protocol of the Paris and Brussels Conventions (2004)
Operator's Liability Cap	91	700
State's Intervention	140	500
Contracting Parties Coverage	150	300
TOTAL	381	1500

Table 1. The different coverage caps before and after the Conventions 2004 amendments (in million €)

This legal regime is very peculiar. Indeed, it makes the national nuclear operator benefit from a subsidy. This subsidy comes from its civil liability limit. This limit creates a bias against the internalisation of the risk costs by the operator because this latter internalises these costs (and covers them) only up to the amount fixed by the Conventions, and thus only partially. Therefore, it is implicitly admitted that if a nuclear accident costs more than this limit (which is more than probable), the operator will not provide complete compensation to the victims. This regime thus protects the nuclear operator and artificially decreases its risk costs. Furthermore, we mentioned before that beyond the operator liability cap, the State intervenes to cover a second risk layer. Doing so, the State pays for the reparations that the nuclear operator does not pay, and *does not have to* pay, pursuant to the Conventions. It thus directly contributes to the lack of internalisation of the risk costs by the operator since it intervenes *ex nihilo* to cover the risk instead of him. The State substitutes for the nuclear operator on this second risk layer, without making the operator pay any price for this financing. We will address below the distortions created by this subsidy, but first, let us compare this subsidy briefly with the situation in the U.S. and then examine what the magnitude of the subsidy is.

B. Compensation in the Price-Anderson Act

Even though we stressed in the introduction that our analysis mainly focuses on the subsidy granted to the nuclear industry resulting from the international liability regime, a brief discussion of the U.S. Price-Anderson Act is interesting, especially to show that in the U.S. it was apparently possible to construct a regime which is far less distorting than the international regime.

Initially the Price-Anderson Act, just like the international compensation regime, limited private liability (up to $60 million).[71] In addition, the government agreed to make an amount of $500 million available.[72] At the time it was passed the Price-Anderson Act surely created a favourable climate for the nuclear American industry.[73] Also, originally in the U.S. a large part of the compensation was awarded through public funds. This, however, changed in 1975 when the public intervention was replaced by a second tier of compensation financed by all American nuclear operators through so-called retrospective premiums.[74] A second change took place in 1975, whereby the individual liability of the nuclear operator was increased to $160 million and the retrospective premiums in the second tier were raised to $400 million.[75] As a result, in 1982, the total amount of compensation under the Price-Anderson Act was $560 million.[76] In fact, it was the same as at the start of the Price-Anderson Act in 1957, with the difference that it was entirely financed by private funds. The most recent amendments to the Price-Anderson Act took place in 2005, as a result of the 2005 Energy Policy Act.[77] Currently, the liability of the individual operator is $300 million.[78] The amount currently available in the second tier is $95.8 million, plus 5% for legal costs per reactor.[79] Since in 2005, 104 reactors were operating, the total amount available was $300 million in the first tier + ($ 95.8 + 5% x $ 95.8) x 104 operators = $10.461 billion for the second tier. In total, this constitutes an amount of $10.761 billion. This can be as follows:

71. *See* Price-Anderson Act, § 4, Public Law 85-256, 71 Stat. 576, 576-77 (1957) (requiring financial protection as the Nuclear Regulatory Commission saw fit); *see also* Barry P. Brownstein, *The Price-Anderson Act: Is It Consistent sith* [sic] *a Sound Energy Policy?*, 36 CATO POL'Y ANALYSIS (Apr. 17, 1984), *available at* http://www.cato.org/pubs/pas/pa036.html.

72. § 4(d), 71 Stat. 577.

73. SAMUEL D. ESTEP, WILLIAM J. PIERCE & E. BLYTHE STASON, ATOMS AND THE LAW 780 (1959).

74. *See* Act of December 31, 1975, Public Law 94-197, 89 Stat 1111.

75. *See id*; *see also* NUCLEAR ENERGY INSTITUTE, PRICE-ANDERSON ACT PROVIDES EFFECTIVE LIABILITY INSURANCE AT NO COST TO PUBLIC 2 (2007), *available at* http://www.nei.org/filefolder/price-anderson_0707.pdf.

76. *See* Tetly, *supra* note 57.

77. Energy Policy Act, Pub.Law. No. 109–58, 119 Stat. 594 (2005). *See also* NUCLEAR ENERGY AGENCY, *Legislative updates*, *in* 23.2 NEA NEWS 32 (2005).

78. *See Legislative updates*, *supra* note 77.

79. *See* 42 U.S.C. § 2210(b)(1), (o)(1) (2009).

Schematic overview of Price-Anderson Act Compensation (in million dollars)				
Year	Individual liability nuclear operator	Additional funding		Total amount available
		Government indemnity	Retrospective premium	
1957	60	500	-	560
1982	160	0	400	560
2005	300	0	10, 461	10,761

Table 2. Schematic overview of Compensation under the Price-Anderson Act

III. CALCULATING THE NUCLEAR SUBSIDY

A. The Level of the Nuclear Subsidy Under the International Regime

The French nuclear subsidy is, as in other countries, related to the operator's liability limit. As mentioned, in accordance with the International Convention requirements, a French nuclear operator must cover the risks he generates up to his liability cap. This coverage is compulsory under the Paris Convention.[80] In French Nuclear Law, the liability cap of the nuclear operator is currently fixed at € 91 million,[81] and EDF (*Electricité de France*), the French nuclear operator, meets its coverage obligation in two distinct ways. For two-thirds, it guarantees it by its financial provisions (up to € 60 million) and for one-third, it purchases insurance (up to € 31 million).[82] As his civil liability is limited to € 91 million, the French nuclear operator benefits from a subsidy equal to the part of the accident costs which would exceed this limit.

Furthermore, we noticed that this financial limit is completed by a second level: the State intervention. Today, this assistance is still limited to a maximum of € 140 million and takes place only if the operator liability cap is insufficient to cover all the accident damages. The State thus intervenes

80. *See* Paris Convention, *supra* note 33, art. 10.

81. Law No. 68-943 of Oct. 30, 1968, Journal Officiel de la République Française [J.O.] [Official Gazette of France], Oct. 30, 1968 (amended by Law No. 90-488 of June 16, 1990, Journal Officiel de la République Française [J.O.] [Official Gazette of France], June 16, 1990).

82. This insurance is contracted through a pool of insurers, Assuratome (with AGF and AXA), and the European mutual ELINI. *See* Fiora, *supra* note 60, at 4 n.9.

for the layer of damages between € 91 million and € 231 million. This assistance is hardly justifiable economically and is, from an efficiency viewpoint, quite unsatisfying. As we will do for the global subsidy, it is interesting to measure the magnitude of this assistance as well. Since this intervention refers to the damages between € 91 million and € 231 million, it is included in the global subsidy (which concerns the damages exceeding € 91 million). As a result, the subsidy refers to the part of the non-internalised risk costs by the operator within which a part is covered by the State (the remaining part being neither internalised nor covered nationally).

Although both of these caps are still the applied caps, we mentioned that the Paris and Brussels Conventions have recently revised them upward. More precisely, the operator financial cap has been increased up to € 700 million and the State's up to € 500 million.[83]

In this respect, it was of prime importance for our analysis to integrate these changes in the evaluation of the subsidy. Indeed, in a previous paper, Fiore attempted to evaluate the French nuclear subsidy,[84] relying on the works of Heyes and Liston-Heyes[85] about the U.S. nuclear liability subsidy in response to Dubin and Rothwell[86] and of Heyes and Liston-Heyes[87] on the Canadian nuclear liability subsidy.[88] The results are instructive. We will not review the mathematical proof within the scope of this paper, but merely present the results. In brief, to calculate the subsidy, Fiore fitted a curve (a function of probability density *f*) relating the magnitude of a nuclear accident (in terms of off-site damages) to its probability of occurrence (assessed by expertise studies). For this, she relied on four scenarios for the evaluation of the "worst-case" damages (noted *Ci= {10,000; 40,000; 70,000; 100,000} million €*) given by the different expertise studies (DGEMP Report;[89] Schieber and Schneider;[90] Spadaro and Rabl;[91] Dubin

83. *See* 2004 Protocol, *supra* note 59, arts. 3(b)(i) & (ii).

84. Karine Fiore, The subsidy of the French nuclear power: An empirical analysis of the Paris and Brussels Conventions liability limit (2006) (unpublished manuscript, on file with author).

85. Anthony G. Heyes & Catherine Liston-Heyes, *Subsidy to Nuclear Power through Price-Anderson Liability Limit: Comment*, 16 CONTEMP. ECON. POL'Y 122.

86. Jeffrey A. Dubin A & Geoffrey S. Rothwell, *Subsidy to nuclear power through Price-Anderson liability limit*, 8 CONTEMP. ECON. POL'Y 73.

87. Anthony G. Heyes & Catherine Liston-Heyes, *An empirical analysis of the Nuclear Liability Act (1970) in Canada*, 22 RESOURCE & ENERGY ECON. 91.

88. Below we will briefly provide a summary of these findings, calculating the subsidy under the U.S. Price-Anderson Act as well. *See infra* Section 2.4.

89. Gen. Directorate for Energy & Raw Materials [DGEMP], *Les coûts de référence de la production électrique* (2003).

and Rothwell)[92] and on the different corresponding probabilities. As a nuclear accident is generated by the reactor core meltdown,[93] Fiore retained the three probabilities generally estimated by the experts for this phenomenon, $P_1=10^{-4}$, $P_2=10^{-5}$ *and* $P_3=10^{-6}$. Refining Dubin *et al.*'s methodology, she relevantly added conditional probabilities, that is, probabilities that reveal the seriousness of the accident resulting from the reactor core meltdown. These probabilities are of two levels. The different Probability Risk Assessment (PRA) studies conducted in several countries generally estimate them at $P_1=0.81$ for "minor" or "medium" accidents (release out of the reactor of 0.1% of inert gases and of 0.01% of the most volatile elements) and $P_2= 0.19$ for "major" accidents (more important releases).[94] In other words, in 8 / 10 of nuclear accidents, radioactive releases are considered weak (this refers to accidents which would cost less than € 500 million) and in 2 / 10, they are estimated to be higher and even of major scope (this refers to "major" accidents which might cost several billion €). The differences between these probabilities reflect the quantity of the radioactive rejections emitted after an accident, and thus its magnitude. In order to make the evaluation of the nuclear subsidy realistic and to provide an accurate estimation of the different levels of risk of a nuclear accident, these conditional probabilities must be multiplied by the probabilities of the reactor core melt P_1 and P_2. Appropriately, Fiore used the probability $P_2= 0.19$ to evaluate the subsidy corresponding to her "worst-case" scenarios (major accidents), going from damages of € 10,000 million to damages of € 100,000 million.

90. C. Schieber & T. Schneider, *Valorisation monétaire des impacts sanitaires et environnementaux d'un accident nucléaire: Synthèse des études ExternE, intérêts et limites de développements complémentaires*, (Sept. 2002), *available at* http://www.cepn.asso.fr/pdf/Rap_Res/R275%20res.pdf.

91. J.V. Spadaro & A. Rabl, *External costs of energy: application of the ExternE methodology in France, Final Report for Contract JOS3-CT95-0010* (1998).

92. Jeffrey A. Dubin & Geoffrey S. Rothwell, *Risk and reactor safety systems adoption*, 42 J. OF ECONOMETRICS 201.

93. We exclude from our analysis the accidents resulting from human mistakes or from external events (natural catastrophes or hostilities) since these events are not foreseeable and thus cannot be affected by a probability.

94. Christian Bataille & Robert Galley , *Rapport sur l'aval du cycle nucléaire, Tome II : Les coûts de production de l'électricité*, Chapitre III, Rep. No. de l'Assemblée Nationale 1359 (1999), *available at* http://www.assemblee-nationale.fr/rap-oecst/nucleaire/r1359-15.asp; NUCLEAR ENERGY ASSOCIATION, POWER GENERATION CHOICES: COSTS, RISKS AND EXTERNALITIES, OCDE, PARIS, FRANCE; US NUCLEAR REGULATORY COMMISSION (1990), SEVERE ACCIDENT RISKS: AN ASSESSMENT FOR FIVE US NUCLEAR POWER REACTORS, 1 NUREG-1150 (1994) (final summary report).

With these data, Fiore found the following values for the French nuclear subsidy:[95]

	$p_1 = 10^{-4}$; $p_s = 0.19$		$p_2 = 10^{-5}$; $p_2 = 0.19$		$P_3 = 10^{-6}$; $p_2 = 0.19$	
Cost of major accidents	R_1=5%	R_2=10%	R_1=5%	R_2=10%	R_1=5%	R_2=10%
C_1 = 10,000	0.67	0.650	0.290	0.280	0.150	0.140
C_2 = 40,000	1.69	1.670	0.610	0.590	0.530	0.490
C_3 = 70,000	2.56	2.500	0.880	0.850	0.650	0.630
C_4 = 100,000	3.3	3.200	1.090	1.010	0.870	0.830

Table 3. The values of the current French nuclear subsidy (in million € reactor year) according to the scenarios

Ri=(R_1; R_2) stands for the share of the risk aversion premium in the total insurance premium

	$p_1 = 10^{-4}$; $p_2 = 0.19$		$p_2 = 10^{-5}$; $p_2 = 0.19$		$p_3 = 10^{-6}$; $p_2 = 0.19$	
Cost of major accidents	R_1=5%	R_2=10%	R_1=5%	R_2=10%	R_1=5%	R_2=10%
C_1 = 10,000	0.320	0.310	0.080	0.079	0.020	0.019
C_2 = 40,000	1.230	1.220	0.315	0.310	0.250	0.230
C_3 = 70,000	2.040	1.900	0.540	0.530	0.360	0.350
C_4 = 100,000	2.800	2.700	0.730	0.670	0.540	0.510

Table 4. The values of the French nuclear subsidy (in million € reactor year) according to the scenarios integrating the 2004 Protocol

These amounts stand for the additional costs the French operator would have to bear if he himself had to cover all his risk costs through insurance.

As Fiore[96] explains, these results show that the amounts of the subsidy are quite important. For the French nuclear park as a whole (fifty-nine reactors), the total subsidy spreads from 8.12 to 191.4 million € / year before 2004 and from 1.1 to 162.4 million € / year after 2004.

95. For more details on the methodology and mathematical proof, *see* Heyes & Liston-Heyes, *supra* note 85; *see also* Dubin & Rothwell, *supra* note 86.

96. Fiore, *supra* note 84.

In sum, with the new Protocol, the French nuclear subsidy decreases at an average rate of 44.2%. Therefore, with the new caps, the operator will bear more risk costs but the State will keep on covering a large part of the risk, and a much bigger part (from € 140 million to € 500 million). Thus, we can say that the global assessment of the 2004 Protocol in terms of subsidy reduction is positive in the sense that the operator will be exposed to damage costs to a substantially higher degree. However, it is not sufficient. The subsidy remains quite high, that is, a significant part of the risk costs keeps on being non-internalised.

B. The Level of the Nuclear Subsidy in the Price-Anderson Act

Above, we stated that the structure of the compensation regime in the Price-Anderson Act in the U.S. is remarkably different from the compensation regime at the international level: the total amount of compensation available to victims in the U.S. is substantially higher than in the international regime and State intervention in the U.S. is excluded. Earlier studies of the Price-Anderson Act have also examined what the scope of the subsidy to the nuclear industry was. First, we should mention that as far as the situation under the Price-Anderson Act of 1957, was concerned (where the operator was only liable for $60 million but the government provided additional funds for $500 million), the NRC argued that the Price-Anderson Act provided a real subsidy to the industry, but that its magnitude was difficult to estimate.[97] In addition, Dubin and Rothwell estimated the cumulative value of the subsidy to industry (in 1985 dollars) to be $110 billion by 1988, and growing to $131 billion by 2001.[98] Later, Rothwell argued that, in economic terms, it is not a direct subsidy in the sense that there is no direct payment made by government to anyone; at the same time he argues that there is a 'potential (or expected) subsidy.'[99] As we stated above, the Price-Anderson Act has been revised many times, taking into account, *inter alia*, the possibilities for the operator to obtain coverage on the insurance market. Today, the U.S. nuclear operator is individually liable for $300 million and in the second layer, an additional amount, is available of $10.461 billion, making the total amount available $10.761 billion.[100]

97. U.S. NUCLEAR REGULATORY COMM'N, THE PRICE-ANDERSON ACT: THE THIRD DECADE G–12 (1983).

98. *See, e.g.*, Dubin & Rothwell, *supra* note 86; Heyes & Liston-Heyes, *supra* note 85.

99. Geoffrey S. Rothwell, *Does the US Subsidize Nuclear Power Insurance?*, STAN. INSTI. FOR ECON. POL'Y RES. (Jan. 2002), *available at* http://siepr.stanford.edu/publications profile/927.

100. *See supra* Table 2.

Without analysing the subsidy under the U.S. Price-Anderson Act in detail, the question can, of course, be asked whether the total available amount in case of a nuclear incident in the U.S. today will be sufficient to cover the costs of an average nuclear incident. That depends to a large extent on the estimates of the costs of a nuclear accident. In the literature, various scenarios are described, whereby the damages range from $10 billion to $100 billion.[101] Depending upon the scenario one follows, there could potentially still be accidents of which the damage is substantially higher than the compensation available under today's Price-Anderson regime. Before the 2005 change, the literature concluded that there was indeed a subsidy resulting from the financial limit on the liability of the operator in the Price-Anderson Act,[102] but depending upon the scenario, this may still be the case today.

Hence, for both the international regime, as well as for the U.S. Price-Anderson Act, it is interesting to examine what the potential consequences are of the nuclear subsidy. Indeed, to the extent that accidents can occur of which the magnitude is higher than the limited amount of compensation available under both regimes there still is an (implicit) subsidy.

IV. THE ECONOMIC CONSEQUENCES OF THE LIABILITY SUBSIDY TO THE NUCLEAR INDUSTRY

The inefficiencies created by a nuclear subsidy, as described in this paper, are of three kinds. Firstly, it might generate an artificial competitiveness of nuclear energy. Secondly, it may not provide the sufficient incentives to the operator to prevent nuclear accidents. Thirdly, the compensation capacity for the victims in case of an accident is made clearly deficient.

A. An Artificial Competitiveness of Nuclear Energy

The default of internalisation of the risk costs by the nuclear operator creates a bias in favour of the competitiveness of his activity because all the costs are not reflected in the kWh price. This argument is a classic embodiment of the theory of market failures and the theory of externalities,[103] according to which, all the costs generated by an economic activity must be integrated into the sale price. On the one hand, this permits the producer to

101. *See supra* section 2.3; *See supra* notes 85 & 86.

102. *See* Rothwell, *supra* note 99.

103. *See, e.g.*, ALFRED MARSHALL, PRINCIPLES OF ECONOMICS (8th ed. 1920); ARTHUR C. PIGOU, THE ECONOMICS OF WELFARE (1920); Ronald Coase, *The Problem of Social Cost*, 3 J. OF L. AND ECON 1 (1960).

recover his costs and to guarantee a minimal profitability. On the other hand, the price becomes an information vector and a signal for consumers.

In regard to the large part of risk costs non-internalised by the nuclear operator, it looks as if the observed competitiveness of his activity is, thus, artificial. Indeed, since he does not internalise the whole risk costs, the nuclear operator integrates these costs only partially in the nuclear kWh price and so passes them on the consumers only partly. As a result, the nuclear kWh price is artificially low and sends a wrong signal to final consumers. This might have two main consequences. First, the consumption of nuclear energy is not at its optimal level; it is "over-optimal." It is higher than it would be if the kWh price reflected the risk costs as a whole (and thus was increased). Secondly, this artificial competitiveness of nuclear energy might stifle the demand for alternative energy sources which, thus, appear much less attractive.

Accordingly, one can wonder what would be the impact of the complete internalisation of the risk costs on the operator's profitability. In other words, one can wonder whether this internalisation would be financially sustainable for the energy producer or not. We can estimate such an impact of the subsidy under the international regime, taking the example of France and its (monopolistic) operator of the fifty-nine nuclear reactors in France, EDF. We take as a financial indicator the EDF's average annual benefit from EDF's financial reports from 2000; that is, € 1.7 billion.[104] Therefore, the value of the supplementary costs (measured by the nuclear subsidy) to this benefit can be calculated in the following tables according to the scenarios:

104. The annual benefits (in billion €) are: 1.141 in 2000, 0.841 in 2001, 0.481 in 2002, 0.857 in 2003, 1.3 in 2004, 3.2 in 2005 and 5.6 in 2006.

	$p_1 = 10^{-4}$; $p_2 = 0.19$		$p_2 = 10^{-5}$; $p_2 = 0.19$		$p_3 = 10^{-6}$; $p_2 = 0.19$	
Cost of Major Accidents	R_1=5%	R_2=10%	R_1=5%	R_2=10%	R_1=5%	R_2=10%
C_1 = 10,000	2.29%	2.22%	0.99%	0.96%	0.51%	0.48%
C_2 = 40,000	5.77%	5.70%	2.08%	2.01%	1.81%	1.67%
C_3 = 70,000	8.73%	8.53%	3.00%	2.90%	2.22%	2.15%
C_4 = 100,000	11.26%	10.92%	3.72%	3.45%	2.97%	2.83%

Table 5. Share of the implicit subsidy to the average EDF's annual benefit before 2004

	$P_1 = 10^{-4}$; $p_2 = 0.19$		$p_2 = 10^{-5}$; $p_2 = 0.19$		$P_3 = 10^{-6}$; $p_2 = 0.19$	
Cost of Major accidents	R_1=5%	R_2=10%	R_1=5%	R_2=10%	R_1=5%	R_2=10%
C_1 = 10,000	1.09%	1.06%	0.27%	0.27%	0.07%	0.06%
C_2 = 40,000	4.20%	4.16%	1.07%	1.06%	0.85%	0.78%
C_3 = 70,000	6.96%	6.48%	1.84%	1.81%	1.23%	1.19%
C_4 = 100,000	9.55%	9.21%	2.49%	2.29%	1.84%	1.74%

Table 6. Share of the implicit subsidy to the average EDF's annual benefit after 2004

According to the scenarios, EDF's subsidy stands for between 0.48% and 11.26% of its average annual benefit before 2004, and between 0.06% and 9.55% thereafter. These ratios are instructive because the full coverage of the risk by the operator seems to be financially sustainable. Therefore, if the French operator covered all of his risk costs in the current situation, he would then pass on his supplementary costs to the consumers. Hence, a relevant question is – What would the price be of the unsubsidised nuclear kWh? This evaluation can be carried out in several ways. An estimate of this impact can be done as follows: dividing the values found for the subsidy by the average number of kWh produced yearly by a nuclear plant in France. We then obtain the proportion of the subsidy (and thus the costs to pass on) per kWh per year. Knowing that a French nuclear plant (of an average capacity of 1000 MW) produces about 7 billion kWh / year, the impact on the nuclear kWh price of the internalisation of the risk costs before and after 2004 are given in the following Tables:[105]

	$p_1 = 10^{-4}$; $p_2 = 0{,}19$		$p_2 = 10^{-5}$; $p_2 = 0{,}19$		$P_3 = 10^{-6}$; $p_2 = 0{,}19$	
Cost of Major accidents	R_1=5%	R_2=10%	R_1=5%	R_2=10%	R_1=5%	R_2=10%
C_1 = 10,000	0.0000957	0.0000929	0.0000414	0.0000400	0.0000214	0.0000200
C_2 = 40,000	0.0002414	0.0002386	0.0000871	0.0000843	0.0000757	0.0000700
C_3 = 70,000	0.0003657	0.0003571	0.0001257	0.0001214	0.0000929	0.0000900
C_4 = 100,000	0.0004714	0.0004571	0.0001557	0.0001443	0.0001243	0.0001186

Table 7. Share of the subsidy per kWh/year (in €) before 2004

	$p_1 = 10^{-4}$; $p_2 = 0{,}19$		$p_2 = 10^{-5}$; $p_2 = 0{,}19$		$P_3 = 10^{-6}$; $p_2 = 0{,}19$	
Cost of Major accidents	R_1=5%	R_2=10%	R_1=5%	R_2=10%	R_1=5%	R_2=10%
C_1 = 10,000	0.0000457	0.0000443	0.0000114	0.0000113	0.0000029	0.0000027
C_2 = 40,000	0.0001757	0.0001743	0.0000450	0.0000443	0.0000357	0.0000329
C_3 = 70,000	0.0002914	0.0002714	0.0000771	0.0000757	0.0000514	0.0000500
C_4 = 100,000	0.0004000	0.0003857	0.0001043	0.0000957	0.0000771	0.0000729

Table 8. Share of the subsidy per kWh/year (in €) after 2004

As expected, this calculation confirms our previous conclusion. Indeed, the nuclear kWh price currently amounts to € 0.03 and nuclear power is one the most competitive energy sources (see Table 9).

105. Fiore, *supra* note 84.

Energy Sources	kWh production cost (€)
Nuclear Energy	0,03
Coal	0,0337
Gas	0,035
Hydraulic	0,04
Fuel	0,05
Wind	0,06
Geothermic	0,06
Biomass	0,10
Solar	0,15

Table 9. KWh production cost of the main power sources in 2008

If we look at the Table 7 and 8 results, the impact of the implicit subsidy, that is of the full coverage of the risk costs by the operator, is weak and the nuclear kWh remains competitive. Without the implicit subsidy, it would amount between € 0.03002 and € 0.0004714 before the 2004 Protocol and between € 0.0300027 and € 0.0304 after. That means that the price would be negligibly affected.

The result is that the full coverage of the risk cost by the French nuclear operator would be financially sustainable for him. It is desirable from economic and social viewpoints and particularly in order to maximize prevention and compensation.

B. A Lack of Prevention

The operator's incentives to prevent nuclear accidents may be affected by the partial internalisation resulting from the nuclear subsidy. Indeed, since the operator does not take into account all of the risks he generates, his behaviour might be inadequate to prevent accidents in an optimal way. Rationally, he will adopt the level of prevention corresponding to the risks he generates. Therefore, if he takes, as a reference, an underestimated level of risks, his preventive actions are necessarily maladjusted and, thus, insufficient to impede an accident. Indeed, the optimality of his level of prevention is determined by the optimality of the level of the considered risks. As a result, a sub-optimal estimation of risks leads to a sub-optimal level of prevention. Such an economic consequence of the lack of internalisation has been analysed in the literature.[106] The partial internalisation of the risk costs, concurrent with the operator's liability cap, is, thus, inefficient in the supply of appropriate prevention incentives. It leads to under-deterrence. This distortion created by the nuclear subsidy is all the more problematic since the potential damages of a nuclear accident are very serious and occur over very long periods of time.

Therefore, to guarantee an optimal level of prevention from the nuclear operator, he should be exposed to his whole risk cost. Nevertheless, even though the operator's level of prevention may be lower than optimal because of the lack of incentives resulting from the nuclear subsidy it is unclear whether this will actually be the case in practice. One should point to the importance of safety regulation as well. The role of the nuclear safety authorities may fill this gap. In this respect, we cited the important role of the IAEA, the NEA and EURATOM in nuclear safety regulation. At an international level, these agencies aim to implement regulatory safety instruments in order to prevent nuclear incidents and accidents.[107] These instruments take the form of standards and recommendations.[108] These safety agencies also exercise a draconian control over the members' countries nuclear installations. In France, the national safety authorities are numerous and organized around the ASN (*Autorité de Sûreté Nucléaire*) and the Ministries of Industry and Ecology.[109] In the U.S., the NRC is in charge of nuclear safety. All of these organizations contribute to improve the application of safety rules on the nuclear installations, and, thus, work to avoid nuclear accidents. Besides, they are much stricter than in any other industrial risky activity.[110]

However, these rules are regulatory and so, do not provide *incentives*, in a strict sense, to the nuclear operator; instead, they provide *obligations*. Even though the purpose is identical (the prevention of accidents), regula-

106. *See generally* Calabresi, *supra* note 43; Brown, *supra* note 44; *Shavell*, *Breach of Contract*, *supra* note 45; *Shavell*, *Nonmonetary Sanctions*, *supra* note 45.

107. *See generally supra* note 12 (the IAEA "helps countries to upgrade nuclear safety and to prepare for and respond to emergencies…The main aim is to protect people and the environment from harmful radiation exposure.").

108. *See id.* (The IAEA Convention on Nuclear Safety serves as an incentive instrument on Parties to strive to achieve higher levels of safety in their nuclear operations.).

109. *See* The French Nuclear Safety Authority, http://www.asn.fr/sections/the-french-nuclear-safety-authority (last visited Jan. 26, 2009) ("The ASN is an independent administrative authority… tasked on behalf of the State, with regulating nuclear safety and radiation protection….").

110. *See generally* U. S. Nuclear Regulatory Comm'n, Regulator of Nuclear Safety, http://www.nrc.gov/reading-rm/doc-collections/nuregs/brochures/br0164 (last visited Feb. 2, 2009).

tion and the liability rules do not employ the same means to reach it. Regulation has a compulsory and external dimension. It is implemented and controlled by an outside and superior authority. The operator is only required to apply and respect the standards it imposes. Therefore, the operator's behaviour changes with the changes of the norms. On the contrary, with a liability rule, the operator is led to modify, on his own, his behaviour in accordance with the risks he generates. Liability rules are thus more dynamic than safety regulation (which is more difficult to change and, as a result, more static). Especially in such a complex industry, it is often argued that liability rules are more efficient, from the prevention of accidents viewpoint.[111] Because the operator has more information about his activity, and more information about its risks, as compared to anyone else (e.g. the regulators), he would be in a better situation to evaluate his risks, and thus, his corresponding level of prevention.[112] Of course, liability rules maintain a punitive dimension by applying sanctions to operators in case of any accidents (strict liability) or in case of accidents resulting from negligence (fault liability).

To sum up, since the nuclear operator's liability is limited, his incentives to prevention are also limited. In such a context, the role of the nuclear safety authorities is crucial to supplement the liability rule. The question remains, to what degree are these authorities complementary, and, correspondingly, what is the efficiency level of their combination.

C. A Lack of Compensation

Finally, a third consequence of the nuclear subsidy refers to the compensation to victims in case of a nuclear accident. Indeed, the current international nuclear liability regime fails regarding the compensatory capacity it provides.[113] In this respect, it is striking to see how low the available amount to cover the nuclear risk is. At a national level, the total nuclear compensation capacity in France currently amounts to € 231 million (€ 91 million from the operator plus € 140 million from the State). At a supranational level, with the additional € 150 million financed by the Conventions' contracting Parties, this amount increases up to € 381 million.[114] In other

111. *See* Faure & Van de Borre, *supra* note 27.

112. *See* Steven Shavell, *A Model of the Optimal Use of Liability and Safety Regulation*, 15 RAND J. OF ECON. 271 (1984).

113. *See generally* Melanie L. Oxhorn, *The Norms of Nuclear Accidents After Chernobyl*, 8 J. NAT. RES. & ENVTL. L. 391(1992).

114. *See supra* Table 1.

words, if a nuclear accident occurs today, the maximum available sum to compensate the victims will only be € 381 million. In consideration of the costs of a major accident, or even of a medium one, this sum is very insufficient.[115]

With the 2004 Protocol, this total available amount raises in the international regime to € 1200 million at a national level, and at € 1500 million at a supranational level. Therefore, if the goal of this Protocol was to make the Paris and Brussels Conventions (amended in 1982) compatible with the other new instruments, such as the modification Protocol of Vienna Convention (1997), its first purpose was to ensure a greater financial compensation of damage in case of an accident.[116] The increased new coverage caps were aimed at compensating a larger number of victims and at covering a broader range of damages suffered.[117] However, we saw earlier that, in spite of the increase of the caps, the operator's subsidy remains high and that a large part of the nuclear risk costs are still neither covered nor internalised. As a consequence, the new amounts of coverage might still be too small to cover many nuclear accidents, particularly major accidents.

Of course, one could argue that insufficient compensation to victims is not an *economic* consequence in the sense that whether or not a victim is compensated is primarily a distributional issue rather than an efficiency issue. However, it has been shown that, particularly with catastrophic losses potentially caused by nuclear accidents, that perspective is too simple. The consequences of such accidents can be that devastating for entire (groups of) countries that, for example, because of affected real estate, may have financial markets that become completely disrupted, if no guarantee can be given that funds are available to compensate the losses and assist in restoration. Recall that the total amount available in the U.S. Price-Anderson Act is substantially higher ($10.76 billion) than in the international regime.[118] Still, also in the U.S. regime, it is still possible that the total amount of compensation will not suffice to compensate all victims. Indeed, in regard to the various scenarios used to quantify the nuclear damages (from $10 billion to $100 billion), the U.S. Price-Anderson Act "only" provides sufficient com-

115. Recall that we mentioned above the costs of a major accident were (in the various scenarios) estimated to vary between € 10 billion and 100 billion. *See* DGEMP Report, *supra* note 89; Schieber and Schneider, *supra* note 90; Spadaro and Rabl, *supra* note 91; Dubin and Rothwell, *supra* note 92.

116. *See* 2004 Protocol, *supra* note 59.

117. *See id.*

118. *See supra* Table 2.

pensation ($10.76 billion) in the case that the most optimistic scenario materialises.[119]

In sum, even if a larger part of the risk costs are now internalised by the nuclear operator thanks to the 2004 Protocol, the goals initially displayed by the parties to the Protocol are not actually reached. From the compensation viewpoint, the amendments are thus clearly deficient. The regime of the U.S. Price-Anderson Act does a lot better in that respect by providing substantially higher amounts of compensation and by having the system entirely financed by the nuclear operators themselves.

V. CONCLUSION

We focused on the international regime for the compensation of damage caused by nuclear accidents as it originated from the OECD / NEA and, more particularly, discussed the existence of a large subsidy for the operator of a nuclear power plant resulting from a financial limit on his liability and State intervention in the provision of compensation. Interestingly, in the 1950s a similar regime originated in the U.S. under the Price-Anderson Act which also had a financial limit on the liability of the nuclear power plant operator as well as State intervention. An important difference between the two regimes is, however, that the U.S., in 1982, completely abandoned the public funding of nuclear damage, whereas the international regime today still, to a large extent, relies on public funding.

However, the regimes still show similarities, for example in the fact that there is still a financial limit on the liability of the nuclear operator. Economists have always been critical of financial limits on the liability of the nuclear operator. The goal of our contribution was hence to use economic analysis to address the potential consequences of a financial limit on the liability of the nuclear operator, which we qualified as a nuclear subsidy.

We argue that there are a few potentially negative consequences from this nuclear subsidy. One consequence is that, to the extent that liability rules provide incentives for prevention, the financial limit on the liability of the operator may lead to under-deterrence. Of course, safety regulation may provide incentives for prevention as well, in addition to the own interest of the operators not to lose their investment in the nuclear plant. However, as a result of the financial cap on liability, the potential complementary function of liability rules in providing additional deterrence is lost. A

119. *See id.*

second effect, which we described as the financial limit (and the resulting nuclear subsidy) is that it may disturb the competition of nuclear energy compared to other energy sources. A result of nuclear energy being subsidised is that relative prices are too low and that, hence, a relatively too high demand will follow as well. Given the enthusiasm of some politicians in favour of nuclear energy, this can be problematic. The increased reliance on nuclear energy should, at the policy level, lead to a debate on why, fifty years after the introduction of nuclear energy, this energy form still deserves an implicit subsidy through a financial limit on liability. Of course, we do realise that other energy sources (particularly fossil fuels like coal and oil) may also enjoy an implicit subsidy as well by not sufficiently internalising the externalities they cause. In those cases, there is at least (usually) no explicit legislative intervention protecting operators from the full exposure to liability law.

Interestingly, the deficiencies in the nuclear liability regime which we found seem to be much more serious in the international regime than in the U.S. Price-Anderson Act. The compensation in the U.S. Price-Anderson Act is substantially larger and government intervention is excluded. The nuclear risk may, therefore, be better internalised in the U.S. than under the international regime. However, even though under the U.S. Price-Anderson Act compensation is substantially larger than under the international regime. Also, in this compensation scheme, it is likely (depending upon the scenario) that a substantial part of the damages will remain uncompensated and are, therefore, not adequately internalised by nuclear operators. By pointing out some of the potentially problematic consequences from the nuclear subsidy from an economic perspective, we argue that policy makers should reconsider the move to nuclear energy as a solution for the climate change problem or radically change the compensation regime to allow for a better internalisation of the nuclear risk and for a better compensation of victims. Politicians should equally realize that both under the international regime and (to a lesser extent) in the U.S., nuclear accidents may occur and the amount of potential damage may largely exceed the available compensation. If no alternative source of compensation is available, this may have serious disruptive effects on the economy.

The reason why nuclear power plant operators enjoy the subsidy we have described and analysed in this paper is, of course, that both the international regime as well as the U.S. Price-Anderson Act can be seen as a result of effective lobbying by the nuclear interest groups. We showed that the nuclear lobby effectively enjoys substantial advantages as a result of the preferential regime. It can, therefore, be expected that substantial efforts will be invested in lobbying in order to maintain these benefits.

However, our paper shows, by analysing the case of the nuclear subsidy in France, that a full coverage of the potential risk costs by the nuclear operator (hence potentially unlimited nuclear liability) would be sustainable for him. The price increase per kWh would moreover not even be substantial. Hence, our paper can also be seen as providing evidence that it is very possible to do away with the nuclear subsidy, thus providing a more adequate internalisation of the nuclear risk, without substantial disrupting effects.