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Nuclear Energy Regulation and the Politics of Social Justice: Technology, Public Goods and Redistribution in Russia and France

By Theocharis N. Grigoriadis¹

Abstract: The paper analyzes the political economy of nuclear power in Russia and France from a social justice perspective. While Russia prioritizes national security over environmental safety, France follows the inverse order of policy priorities. Nuclear innovation defines the ability of any state to provide efficiently public goods and implement redistributive policies, based on its nuclear potential. The distinction between hierarchical and multilevel regulation of the nuclear sector in Russia and France is critical for my argument; because hierarchical regulation is less likely to facilitate innovation, emerging nuclear-intensive economies are less inclined to approximate energy-induced redistributive justice. Explaining the four possible outcomes of the French-Russian nuclear cooperation, I maintain a high degree of optimism that technology can serve the needs of the poor without hampering global sustainability, growth and international investment relations.

Keywords: social justice, redistribution, France, Russia, sustainability, regulation, nuclear power, innovation, public goods, Rosatom, EDF, electricity

I. Introduction

Why do industrial economies differ in their nuclear power strategies? What accounts for the persistent politicization of nuclear power twenty years after the end of the Cold War? Does nuclear power serve the interests of the state or its citizens? I define the political economy of nuclear power as a multidimensional policy space defined by two components: provision of public goods and social redistribution. Public goods refer to the promotion of a carbon-free environment and the strengthening of a government's deterrence capacity. Redistribution refers to the policy set transferring private goods from the rich to the poor. This policy set includes reduction of electricity prices, increase of employment rates and market development in the oil and gas sectors, particularly in economies that have opted for a state model of ownership and oversight in the energy industry.² Safety and sustainability constitute the necessary foundations for both redistribution of private goods and provision of public goods. Thus, I suggest an

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² World Energy Outlook. "Are Conditions Right for a Nuclear Revival?". *Fact Sheet – Nuclear* 2006.

ordered sequence of nuclear policy preferences for any industrial economy: *sustainability* \geq *public goods* \geq *redistribution*. The focus of this paper is to test whether this sequencing holds for Russia and France, two very different political and economic systems, which are both committed to the expansion of their nuclear technology potential.³

The selection of the nuclear reactor design becomes a key factor, when it comes to the ordering of these preferences; the typology of innovative nuclear reactors is defined by four characteristics: primary coolant, operating conditions, moderator features and nuclear power applications.⁴ There seems to be a strong correlation between the type of the coolant and the power generation capacity of the reactor. Light water, heavy water, gas, molten salt and liquid metal form an ordered axis, where light water is on the lowest generation capacity pole and liquid metal on the highest.⁵ Moreover, Russian vast uranium reserves and French growth dependence on nuclear power generation suggest that nuclear energy will obtain an increasingly important role in global energy security.⁶ France is the most nuclear-intensive economy on the planet after the fall of the Soviet Union; at the same time, Russia's nuclear disadvantage, largely due to the construction of most Soviet nuclear infrastructure in Ukraine, has been gradually offset by increased oil and gas state revenues.⁷ The complementary character of civil nuclear energy to its military applications provides an additional argument for the extensive use of nuclear energy in states with high electricity demand, commitment to a strong public sector and great power status. Uncertainty in the use nuclear power has necessitated its industrial development under the institutional auspices of the government. In France, the key nuclear policy actors are the Commission on Nuclear Energy, EDF (the public electricity company), and the Areva Group, which is the corporate implementation pillar of nuclear projects at home and abroad.⁸ In Russia, the system is much more centralized; there is one state

³ For more information on Russian nuclear energy policy, see Dorian James P. et al. "Global Challenges in Energy". *Energy Policy* 34 (2006): 1984-1991.

⁴ OECD/IEA. "Innovative Nuclear Reactor Development: Opportunities for International Cooperation". *OECD/IEA Report*, 2002: 23.

⁵ OECD/IEA. "Innovative Nuclear Reactor Development: Opportunities for International Cooperation". *OECD/IEA Report*, 2002: 25-27.

⁶ CEA. "Memento Sur l'Énergie - Energy Handbook". *Edition 2008*: 12.

⁷ CEA. "Memento Sur l'Énergie - Energy Handbook". *Edition 2008*: 21-22.

⁸ Finon Dominique. "The Mitigation of the French Nuclear Option: New Industrial Realism and Technical Democracy", *Energy & Environment*, Vol. 13, No. 2, May 2002: 263-279.

corporation, Rosatom.⁹ The state corporation has been the new organizational form that the Russian government has chosen to treat key industrial sectors with a strong public interest component. Rosatom includes under its auspices the following four units: 1. OAO Atomenergoprom 2. Nuclear military complex 3. Fundamental science and 4. Nuclear and radiation safety.¹⁰ This dichotomy between *hierarchical and multilevel nuclear energy regulation* in Russia and France is a key proxy for my analysis.

The paper is organized as follows. In Section 2, I analyze the impact of nuclear technology development on the provision of public goods and then I compare the politics of nuclear policy in Russia and France in terms of the policy preferences of the political elites and the vertical vs. horizontal administrative organization of the nuclear sector. In Section 3, I elaborate on the regulatory role of nuclear energy agencies with special focus on social redistribution. In Section 4, I suggest a research design to explore the multiple interactions between nuclear policy preferences, organization and social justice. In Section 5, I discuss my findings.

II. Nuclear Technology, Regulatory Systems and Public Goods

The development of nuclear reactor technology is pivotal for efficiency in power production and reduction of electricity prices; 2nd generation nuclear reactors since the 1970s and 1980s constitute the majority of nuclear reactors around the world, since the Chernobyl accident in Ukraine discouraged many governments from ordering the construction of 3rd generation reactors.¹¹ This is the reason why the design of 4th generation nuclear reactors has already been launched; the new reactors proposed have a higher degree of passive safety, reduce long-life waster production and are less capital-intensive.¹² They address all major concerns that have so far prevented the expansion of nuclear-intensive electricity production in many advanced and the majority of developing economies. In parallel, the intensive exploitation of current uranium

⁹ Rosatom. "Dokumenty Goskorporatsii Rosatom", 2008.

¹⁰ Rosatom. "Dokumenty Goskorporatsii Rosatom", 2008; see also Hecker Siegfried. "Thoughts about an integrated strategy for nuclear cooperation with Russia", *The Nonproliferation Review*, Summer 2001.

¹¹ OECD/IEA. "Nuclear Power". *IEA Energy Technology Essentials*, March 2007: 1.

¹² OECD/IEA. "Nuclear Power". *IEA Energy Technology Essentials*, March 2007: 2-4.

reserves combined with the discovery of new ones is likely to transform the resource base of many advanced and transitional economies by creating a long-term source of public revenues.¹³ Unlike the oil and the gas industries, the nuclear energy sector is under the direct supervision of the state. Furthermore, nuclear power is not exported directly to the world markets, but it serves as a resource base for the operation of electricity industry. Given the central social role of electrical power in consumer welfare, it becomes obvious that nuclear power can conditionally become a useful instrument in the hands of governments intending to increase their probability of reelection. The primary public goods provided by a nuclear-intensive economy are environmental protection through pollution abatement and national security through the expansion of nuclear infrastructure for military technology purposes. Although nuclear energy was symbolically excluded from the Kyoto compliance mechanism in the time period of 2008-2012, it is not likely that this will continue to be the case in the post-adjustment period, when the Clean Development Mechanism of the Protocol (CDM) will enter into force.¹⁴ Opponents of nuclear energy expansion contend that nuclear infrastructure entails extremely high sunk costs, does not prevent the proliferation of nuclear weapons and provides insufficient guarantees for nuclear waste disposal and decommissioning while undermining innovation in the electricity sector as a whole.¹⁵ The argument proposed against nuclear technology development is that the ecological and security risks associated with nuclear energy are so immense that they offset the positive impact of public goods provided by it.¹⁶

At this point, it becomes necessary to define what a *nuclear-intensive* economy is. I argue that it has the following characteristics: 1. It operates at above average levels of electricity consumption, due to its population size, climate or both 2. It enjoys a sufficient degree of macroeconomic stability and therefore can afford to pay the high sunk costs required for the construction of nuclear infrastructure 3. The development of renewable energy technologies does not constitute a central energy policy priority of the government, independently of which party or group is in power and 4. The state intends to maintain a suboptimal security advantage in the international community. These four prerequisites do not have to be jointly met so that an

¹³ CEA. "Memento Sur l'Énergie - Energy Handbook", 2006: 12.

¹⁴ OECD/Nuclear Energy Agency. "Nuclear Energy and the Kyoto Protocol" *OECD/IEA Report 2002*: 29-34.

¹⁵ Schneider Mycle. "Changement Climatique et Énergie Nucléaire", WWF, Aout 2000 : 3-6.

¹⁶ For the Canadian-US nuclear experience and the role of public participation, see Kraft Michael E. "Policy Design and the Acceptability of Environmental Risks: Nuclear Waste Disposal in Canada and the United States". *Policy Studies Journal*, Vol. 28, No. I, 2000: 206-218.

economy is *nuclear-intensive*. This form of nuclear-intensive provision of public goods such as pollution abatement and national security is possible either in advanced capitalist economies with a high GDP per capita, large population or/and idiosyncratic climate or in transitional/developing economies with high growth rates, large population or/and idiosyncratic climate. Thus, nuclear-intensive economies can be divided into advanced and emerging ones. I argue that the difference between *advanced* and *emerging nuclear-intensive economies* is that advanced economies are likely to prioritize pollution abatement over national security; the inverse inequality holds for emerging economies. This is the reason why France and Russia offer compelling cases for my hypothesis. They are both committed to nuclear energy rather than renewable energy resources and they are both interested in preserving their comparative advantage in the international system.¹⁷ Nevertheless, they share different political and economic systems, and this reflects in their macroeconomic situation and therefore their pace in the development of nuclear infrastructure and technology.

The full nuclear power chain emits the same amount of carbon as solar or wind energy and two magnitude orders less than oil, coal or gas.¹⁸ Moreover, it becomes evident that nuclear technology has to concentrate in industrial applications other than electricity production; clean water supply and transportation are the two areas where the contribution of nuclear power is likely to become increasingly important.¹⁹ At this point, it becomes critical to understand the status of nuclear technology infrastructure in the Russian Federation and what is the role of the regulatory system designed by the Kremlin in that respect. Russia maintains three types of organizational entities in its nuclear sector: 1. Atomic energy stations (10) 2. Processing companies (4) and 3. Exploration companies (4).²⁰ In the Russian nuclear sector, there are thirty-one reactors; out of these, there are fifteen pressurized water reactors (nine VVER-1100 and 6 VVER-440), fifteen channel boiling reactors (eleven high power channel type reactors - RBMK-

¹⁷ To comprehend the national security dimensions of nuclear energy see for Russia, Trenin Dmitri. "Russia's Nuclear Policy in the 21st Century Environment", *Proliferation Papers*, Security Studies Department, IFRI 2005.

¹⁸ Sokolov Yury A. et al. "Nuclear Power in the 21st Century and its role in Developing Countries". *An International Journal of Nuclear Power*, Vol. 18, No. 2-3 (2004): 24.

¹⁹ Sokolov Yury A. et al. "Nuclear Power in the 21st Century and its role in Developing Countries". *An International Journal of Nuclear Power*, Vol. 18, No. 2-3 (2004): 25-26.

²⁰ Rosatom. "Geografiia Atomnykh Obektov", 2008.

1000- and four graphite channel power reactors with steam overheating – EGP-6) and one fast neutrons reactor (BN-600).²¹

What we observe is the operation of mainly generation II reactors since the Cold War period (1965-1995).²² Rosatom, the federal agency on atomic energy, provides the necessary institutional nexus for both the domestic and overseas activities of the national nuclear industry. Its organization as an M-form organization confirms a key trend in Russian political economy under Putin: instead of maintaining deficient U-form organizations of public ownership, the Russian government has launched a multidivisional organization strategy with the combination of state control and corporate profitability.²³ Hence, while the public character of the nuclear sector is maintained, its focus of interest shifts from domestic to external operations; Atomstroyexport and Tenex, the nuclear constructor and uranium trader for overseas operations respectively, become the drivers of Russia's nuclear capacity.²⁴ This observation may lead to two significant conclusions: 1. Nuclear innovation in Russia is likely to be the outcome of foreign capital inflows and corporate competition over contracts in the developing world 2. The complementary nature of civil to military nuclear technology and the absence of checks and balances in the Russian political system lead to the prioritization of defense over pollution abatement and the creation of an international nuclear network dependent on the Russian nuclear know-how, civil and potentially military.²⁵ This external dimension of the nuclear industry does not resemble to the corporate emblem of Russia's energy sector: Gazprom. Unlike natural gas, nuclear energy can be exclusively used for electricity generation; its high initial capital costs allow a much smaller group of countries, which I previously defined as nuclear-intensive, to obtain access to it.²⁶ Hence, the Russian government can trade uranium on a more selective basis; nevertheless, long-term financial

²¹ Rosatom. "Atomnaia Energetika v Rossii", 2008.

²² See Table 1 in the Appendix.

²³ Rossiiskaia Federatsiia. "Federalnii Zakon o Gosudarstvennoi Korporatsii po atomnoi energetike Rosatom". December 1 2007.

²⁴ IAEA. "Milestones in the Development of a National Infrastructure for Nuclear Power", *IAEA Nuclear Energy Series*, No. NG-G-3.1.

²⁵ See the monopoly role of the Russian government in nuclear energy regulation in Rossiiskaia Federatsiia. "Federalnii Zakon ob Ispolzovanii Atomnoi Energetiki". October 20 1995.

²⁶ OECD/Nuclear Energy Agency. "Nuclear Energy in a Sustainable Development Perspective" *OECD/IEA Report 2000*: 10-16.

benefits, wealth and population size of its customers provide innovation incentives, comparable with the natural gas sector.

The nuclear industry is more significant for the French rather than the Russian economy. While Russia's hybrid combination of technical expertise and fuel fossil-induced growth rates classify it as an emerging nuclear-intensive economy, France constitutes the model of an advanced nuclear-intensive economy. The French government has been consistently financing the development of nuclear infrastructure since the construction of generation II reactors.²⁷ Moreover, EDF, the state-owned electricity corporation, has been the main beneficiary of France's increasing role as an advanced nuclear-intensive economy. The emergence of EDF as a global actor in electrical power generation and infrastructure is largely due to that factor. This is the reason why safety has been the central priority of French nuclear policy since the end of the Cold war. Unlike Russia, France has prioritized pollution abatement over defense and its commitment to generation III and III Plus nuclear reactors consolidates this policy objective. The use of passive safety systems, the reduction of the core fusion probability and the confinement of environmental consequences in the case of an accident constitute some of the key measures taken en route to the modernization of nuclear infrastructure.²⁸ Furthermore, I observe a set of multilevel organizations, administrative and corporate, rather than an M-form corporate organization of public ownership. The Commission of Atomic Energy is an administrative agency, while Areva and EDF constitute different models of public corporate governance, focused on generation and infrastructure construction respectively.²⁹ There are fifty-nine operative reactors in France with total capacity of 63260 MW.³⁰ Nuclear energy regulation in France is not a single-dimensional public policy space; it combines both state and market segments that adapt regulatory decisions to domestic risk perceptions and international competition. This approach is also justified by the risk perceptions expressed by French public opinion; both the merits and the risks of nuclear energy dependence are acknowledged and

²⁷ CEA. "Les systèmes du futur". *Dossier de Presse*, Janvier 2006 : 4-5.

²⁸ CEA. "Les systèmes du futur". *Dossier de Presse*, Janvier 2006 : 7; see also CEA. "Le Réacteur Osiris". *Direction de l'énergie Nucléaire*.

²⁹ Finon Dominique. "The Mitigation of the French Nuclear Option: New Industrial Realism and Technical Democracy", *Energy & Environment*, Vol. 13, No. 2, May 2002: 263-279.

³⁰ International Atomic Energy Agency. *Nuclear Technology Review 2008*. Vienna 2008: Table A1, p. 5.

taken seriously into account.³¹ Thus, nuclear innovation in France is the outcome of domestic public pressures and international safety standards. The existence of a strong anti-nuclear movement led to an increase of control standards in nuclear facilities in the 1970s and the 1980s; the institutional organization of pro-nuclear forces at higher levels of central government explains why the French nuclear program has been the most successful in its implementation in Europe.³² Because all advanced economies are obliged to make the choice between nuclear and renewable technology development and France has clearly chosen the nuclear pathway, the reinforcement of French-Russian nuclear cooperation is very likely to occur. This will be the case not only in the area of nuclear waste disposal but also in the exploration and trading of uranium from the former Soviet Union to Western Europe and the development of common safety norms across the continent.³³

III. Nuclear Power, Redistribution and Social Justice

I suggest that nuclear energy regulation in Russia prioritizes defense over pollution abatement, while the inverse holds for France. I also propose that multilevel rather than hierarchical regulation of the nuclear energy sector is more likely to lead to high degrees of innovation. Then the question that comes to mind is the following: how does the choice of nuclear energy development advance people's welfare, and in particular, the welfare of the lower social strata? To answer these critical questions, it is necessary to link nuclear intensity and the nature of nuclear regulatory systems in Russia and France with the impact of nuclear redistribution on people's welfare. It is clear that nuclear-intensive economies, where nuclear power accounts for less than 50 percent of electricity production, are not likely to use nuclear energy as a channel of income redistribution in favor of their poor citizens. Thus, I argue that there is a redistribution threshold $E(N^*) \geq \frac{E(T)}{2}$, where $E(N^*)$ is the optimal nuclear-based electricity generation and

³¹ Wiegman Oene et al. "Perception of Nuclear Energy and Coal in France and the Netherlands". *Risk Analysis* Vol. 15, No. 4 (1995): 518-521.

³² Rucht Dieter. "Campaigns, Skirmishes and Battles: Anti-nuclear Movements in the USA, France and West Germany", *Organization & Environment* Vol. 4, 193, 1990: 200-203.

³³ Ministère de l'Économie, des Finances et de l'Industrie. "Réserves Mondiales Prouvées de l'Uranium (1.1.2006)". *Observatoire de l'énergie d'après AIEA/OCDE 2006*; see also World Nuclear Association. "The Economics of Nuclear Power". *Information Papers*, August 2008.

E(T) is the total electricity production in any national economy.³⁴ The rationale here is that unless nuclear energy constitutes a major resource base for electricity production in any economic system, it does not lead to lower electricity prices for citizens.³⁵ High temperature nuclear reactors using gas, molten salt or liquid metal as their coolant lead to more efficient thermochemical and electrochemical hydrogen production.³⁶ This research finding indicates that the shift to high temperature nuclear reactors may have a positive impact on nuclear power-induced redistribution. Moreover, the inefficient technology of light-water reactors, which was applied by the US Navy immediately after the end of WWII, has shown that nuclear technology development may benefit the lower classes, when its primary focus are the civil rather than military applications of nuclear power.³⁷ At this point, it becomes clear that innovation is a sine qua non component of nuclear energy redistribution in Russia and France; the substitution of fission with fusion as delineated in the ITER project indicates that sustainability is an inherent feature of a redistributive nuclear energy industry.³⁸

In Russia, the current locus of energy redistribution is in the natural gas rather than the nuclear energy sector. Unlike Gazprom, whose domestic and international corporate activities are regulated by not only the Russian government, but also WTO, the European Commission, foreign governments and transnational arbitration courts, Rosatom is subject only to the decision-making authority of the Kremlin. Hierarchical regulation by a single state jurisdiction does not provide sufficient innovation incentives, which would approximate $E(N^*)$ to $\frac{E(T)}{2}$ in the Russian economy.³⁹ Nevertheless, Russia's nuclear intensity is due to drastic increase of uranium exports and the flourishing overseas construction activities of Atomstroyexport. Hence, the increase of nuclear energy revenues in Russia is the only condition, able to generate redistributive outcomes for the nuclear sector. I suggest $R(n^*) = \frac{R(e)}{n}$, where $R(n^*)$ indicates the

³⁴ World Nuclear Association. "The Economics of Nuclear Power". *Information Papers*, August 2008.

³⁵ World Nuclear Association. "The Economics of Nuclear Power". *Information Papers*, August 2008.

³⁶ Yildiz Bilge and Mujid S. Kazimi. "Efficiency of hydrogen production systems using alternative nuclear energy technologies", *International Journal of Hydrogen Energy* 31 (2006): 78-79.

³⁷ Cowan Robin. "Nuclear Power Reactors: A Study in Technological Lock-in". *The Journal of Economic History* Vol. 50, No. 3 (Sep. 1990): 541-567.

³⁸ Fiore Karin. "Nuclear Energy and Sustainability: Understanding ITER", *Energy Policy*, Vol. 34 (2006): 3336-3338.

³⁹ Kryukov Oleg V. "Nam Doveriyaiut Atomshchiki 14 Stran Mira", *Atomnaia Strategia* No. 25: Glavnaia Tema, Sentiabr' 2006.

optimal volume of state revenues from the nuclear sector, $R(e)$ is the volume of state revenues from all energy markets in any economy and n is the number of energy markets. I argue that redistribution through the nuclear power sector is likely to occur when the revenues from the nuclear power sector approximate those from other energy markets, particularly in oil- and natural gas-intensive economies.

Gradual adjustment to IAEA standards and technical cooperation with Areva on the sustainability of the nuclear fuel cycle as well as safety measures drive Rosatom toward a multilevel regulatory system.⁴⁰ The provision of state credit guarantees by the Bank of Foreign Trade (Vneshtorgbank), Russia's second largest financial retailer, is a key aspect of Russia's new atomic strategy.⁴¹ I argue that the consolidation of an export partnership between RAO UESR, Russia's electricity company, and Atomenergoatom is likely to increase Rosatom's international competitiveness, and thus diversify the sources of domestic nuclear revenues. This two-stage policy outcome may transform nuclear power regulation from a hard to a soft policy area; the atomic priorities of the Russian government are then likely to shift toward new business strategies.⁴² It becomes obvious that the redistributive capacity of the Russian nuclear sector is a second-order condition, contingent upon the strengthening of its quota in domestic electricity production, shift to multilevel regulation and boost of international competitiveness. The design of the fast neutrons nuclear reactor (BN-800), which abides by international standards, is a first signal that Russia is moving toward a multilevel model of nuclear governance.⁴³

In assessing the redistributive effects of nuclear energy regulation in France, it becomes clear that Electricité de France (EDF) is the common denominator of all social policy developments in the French nuclear sector. Not only it is the largest nuclear-based electricity company in the world, but it has also been able to meet domestic and international demand with low price volatility and high degree of supply certainty.⁴⁴ Furthermore, the zero reduction target set by

⁴⁰ Kryukov Oleg V. "Nam Doveriyaiut Atomshchiki 14 Stran Mira", *Atomnaia Strategia* No. 25: Glavnaia Tema, Sentiabr' 2006 and Kamalova F. R. "VTB kak gosudarstvennyi bank budet uchastvovat' v proektakh Rosatoma", *Atomnaia Strategia* No. 25: Kontseptsia Razvitiia, Sentiabr' 2006.

⁴¹ Kamalova F. R. "VTB kak gosudarstvennyi bank budet uchastvovat' v proektakh Rosatoma", *Atomnaia Strategia* No. 25: Kontseptsia Razvitiia, Sentiabr' 2006.

⁴² Kungurov Yu. A. "Organizatsionnye i Finansovye Aspekty Reformirovaniia Atomnogo Energopromyshlennogo Kompleksa Rossii". *Aval* Mart-April 2' 2008: 29-30.

⁴³ Rineiskii Anatolii A. "Inzhiniring Energobloka s Reaktorom Na Bystrykh Neitronakh BN-800: Sravnenie s Mirovymi Analogami", *Atomnaia Strategia*, No. 23: Atomnye Tekhnologii.

⁴⁴ See also OECD/IEA. "Nuclear Power in Competitive Electricity Markets" *OECD/IEA Report* 2000.

the French government as a response to the Kyoto Protocol adjustment requirements indicates that nuclear energy saves citizens from additional environmental taxation; the internalization of externalities through governmental funds rather than an emissions trading system does not transpose the social cost equally to all strata, but it confines it within formal political institutions.⁴⁵ Thus, state responsibility rather than collective contributions solves the pollution abatement problem by requiring a relatively low threshold of carbon emissions cost per ton (50 USD).⁴⁶ The high nuclear intensity of the French economy ($E(N^*) \geq \frac{E(T)}{2}$) provides an interesting tradeoff between the cost of decommissioning and nuclear waste disposal on the one hand and carbon emissions taxation on the other for the benefit of the former.

The steady and consistent transition from nuclear reactors of generation II and III to nuclear reactors of generation IV is the crucial difference between the political economies of nuclear power in Russia and France.⁴⁷ This phenomenon is partially explained by France's revenue dependence on nuclear energy rents and Russia's revenue dependence on natural gas rents; this means that nuclear innovation in France is associated with higher expected revenues for the state and therefore lower negative externalities for the citizens. Instead of modeling sustainability, public goods distribution and social redistribution as an ordered sequence of preferences (*sustainability* \geq *public goods* \geq *redistribution*), it may be more useful to set them up in the form of a three-level model; in this case, redistribution implies the distribution of public goods through the nuclear sectors, and public goods provision is dependent on the black box term of sustainability. If nuclear sustainability is modeled as $S(X,Y)$, where X is the amount of cost effectiveness and Y the level of environmental externalities, then public goods provision is $G(S(X,Y))$ and redistribution is $R(G(S(X,Y)))$. What I observe is the definition of a *composite nuclear redistribution*. The introduction of fusion technology in the design of nuclear reactors is an extremely important step in that direction;⁴⁸ unlike the gas sector, where innovation does not necessary lead to redistribution for the benefits of the citizens, nuclear innovation is a win-win situation for both the citizens and the state.

⁴⁵ OECD/IEA. "Nuclear Power in Competitive Electricity Markets" *OECD/IEA Report 2000*: 52.

⁴⁶ OECD/IEA. "Nuclear Power in Competitive Electricity Markets" *OECD/IEA Report 2000*: 54.

⁴⁷ CEA. "Produire de l'Énergie sans Gaz d' Effet de Serre: L'action du CEA". *CEA Dossier de Presse*, 28 Octobre 2008.

⁴⁸ CEA/Cadarache. "ITER a Cadarache" 2005; for the opposite opinion see Martinez-Val Jose and Mireia Piera. "Nuclear fission sustainability with hybrid nuclear cycles", *Energy Conversion and Management* 48 (2007): 1480-1490.

I argue that the principal-agent model works for the delineation of state-society relations in the French nuclear sector. However, it may become problematic when it applies to technology transfers from the advanced to the developing world;⁴⁹ social welfare in the recipient of innovation strategies may become contingent on the decisions taken by the policy-makers of the advanced innovation partner. French nuclear dominance in Europe has already been constrained by EC competition rules;⁵⁰ in any case, the increased safety risks and high sunk costs require an extensive regulatory capacity by the central government. Because the adherence to the non-processing fuel cycle is the best strategy for both power generation and nonproliferation purposes, state responsibility may be the only sufficient regulatory clause to confine nuclear waste disposal risks within limited and solid institutional boundaries.⁵¹

IV. Hypotheses and Research Design

The theoretical analysis presented above leads us to the following set of hypotheses:

1. Main Hypotheses

H1: *Multilevel rather than hierarchical regulation is likely to lead to high degrees of nuclear innovation.*

H2: *When $E(N^*) \geq \frac{E(T)}{2}$, social redistribution through the nuclear sector is more likely than in the inverse case.*

H3: *The French government prioritizes safety over national security while the inverse holds for the Russian government.*

H4: *Higher state revenues from nuclear power generation increase incentives for innovation and social redistribution.*

2. Corollaries

C1: *The M-form structure of Rosatom combines organizational efficiency and direct state control in nuclear energy regulation at the expense of innovation.*

⁴⁹ Damian Michel. "Sustainable Development: The Last Chance for Nuclear Power?" *Energy Studies Review* Vol. 6 No. 1, Art. 5, 1994: 82-83.

⁵⁰ Finon Dominique. "Reforms in the French power system: from weak contestability to effective competition?" *Energy Policy*, Vol. 29 (2001): 756-759.

⁵¹ Von Hippel Frank N. "Plutonium and Reprocessing of Spent Nuclear Fuel", *Science*, Vol. 293, September 28 2001: 2398.

C2: *The dominant market position of EDF in the French nuclear industry facilitates innovation and social redistribution at the expense of competition.*

What is the role of nuclear energy in advancing social justice? I treat social justice as an infinite form of social redistribution. To provide a primary analytical design on the interaction between nuclear power regulation and social justice, I suggest the following 2 by 2 matrix:

Matrix 1: Nuclear Technology and Social Justice

Nuclear Intensity →	Advanced Economies → $E(N^*)$ (High)	Emerging Economies → $E(N^*)$ (Low)
Nuclear Technology ↓		
Reactor Type ≥ Generation III (High)	<i>Approximate redistributive justice</i>	<i>Poverty reduction</i>
Reactor Type = Generation II (Low)	<i>Income inequality</i>	<i>Negative externalities</i>

where nuclear technology forms the first axis of analysis and nuclear intensity constitutes the second axis of analysis. I classify nuclear technology into two categories according to the types of nuclear reactors being predominant in any economy; a high value is assigned to nuclear reactors of generation III or higher, whereas I assign a low value to generation II nuclear reactors. Nuclear intensity is determined by the aforementioned binary typology between advanced and emerging nuclear-intensive economies. I assume that in advanced nuclear-intensive economies, the level of optimal nuclear-based electricity generation is higher than in emerging nuclear-intensive economies.

I am convinced that when nuclear reactors of generation III or higher are observed in an advanced nuclear-intensive economy, then approximate redistributive justice becomes possible **(High, High)**, because positive social redistribution occurs for the benefit of the lower social strata. Thus, innovation generates redistributive effects for the poor in the form of lower prices and cleaner environment. In the lower left entry of the matrix **(High, Low)** the government in an advanced nuclear-intensive economy decides not to innovate. In that case, the government may impose an emissions trading system, which will lead to electricity price increases without the existence of any offsetting welfare mechanism. Thus, income inequality under these conditions is likely to increase. In the upper right entry **(High, Low)** I analyze the prevalence of high nuclear technology in an emerging nuclear-intensive economy; nuclear innovation has again a positive impact on the social welfare of the lower strata, but due to the developing

rather than developed character of the economy, redistribution is materialized in indirect terms: poverty reduction may capture this phenomenon. The lower right entry (**Low, Low**) suggests the worst out of four scenarios; lack of nuclear innovation in any developing economy transposes negative externalities and uncertainty costs to the citizens' shoulders.

I now turn to the scenario of French-Russian nuclear cooperation. I regard it as an extremely vital development for global nuclear security, given my aforementioned distinction between advanced and emerging nuclear-intensive economies. To illustrate the dynamics of the French-Russian nuclear interaction, I propose the following 2 by 2 matrix:

Matrix 2: French-Russian Nuclear Cooperation

Recipient (Russia) →	Adjustment to International Norms →	Maintenance of the Status Quo →
Innovator (France) ↓	Open Nuclear System (High)	Closed Nuclear System (Low)
Construction of Nuclear Reactors (High)	<i>Global Sustainability</i>	<i>Political Alliance</i>
Nuclear Waste Disposal (Low)	<i>Transnational Governance</i>	<i>Ad Hoc Contracts</i>

where France as the innovator forms the first axis of analysis and Russia as the technology recipient forms the second axis of analysis. I define the nuclear policy choices of France in terms of its cooperation potential with Russia; it spans between nuclear waste disposal (Low) and nuclear reactor construction (High). Russia's nuclear policy choices are determined in terms of its adjustment to international nuclear energy standards as these are defined by the advanced nuclear economies and the IAEA; thus, Russia is faced with a binary choice between adjustment to international norms (High) and maintenance of the status quo (Low).

I propose that if Russia adjusts to international nuclear energy standards and France agrees to provide the necessary expertise for the construction of generation III or higher nuclear reactors, then global sustainability occurs (**High, High**). The regulatory coordination between France and Russia, the two main nuclear powers of Eurasia, is likely to have a positive effect on global governance of the nuclear sector.⁵² In the lower left entry of the matrix (**Low, High**) France prefers to limit its nuclear cooperation with Russia at the level of nuclear waste disposal, while Russia adjusts to international nuclear standards. This combination of preferences generates a

⁵² For an overview of the argument on the politics of international regulatory coordination, see Drezner Daniel W. *All Politics is Global: Explaining International Regulatory Regimes*. Princeton University Press 2007.

mode of transnational governance, where I observe the indirect internalization of French nuclear standards by Russian policy makers through international channels. In the upper right entry (**Low, High**), I analyze the implications of nuclear technology transfers from France to Russia, when the latter preserves the status quo. If France contributes to the modernization of the Russian nuclear sector without any institutional adjustments from Moscow, this will occur under conditions of political alliance. The lower right entry (**Low, Low**) shows that when no player moves from its initial position, ad hoc contracts take place; uranium exports, occasional nuclear waste disposal, and common innovation projects form the basis of this category.

V. Discussion

In this paper, I discussed the politics of nuclear energy regulation and social justice in Russia and France. I observe a clear divide between advanced and emerging nuclear-intensive economies using France and Russia as my case studies; while Russia prioritizes national security over environmental safety, France follows the inverse order of policy priorities. The distinction between the Russian and French nuclear regulatory systems may account for this difference in policy priorities. Multilevel nuclear regulation in France requires the involvement of public and private actors at multiple levels of governance. Hierarchical nuclear regulation in Russia creates an M-form organizational space, where corporate organization meets public oversight. The nuclear energy dependence of any economy predicts its level of nuclear innovation; although French nuclear intensity may be an extreme case, this argument can be extended to other advanced nuclear-intensive economies with a lesser degree of energy dependence from nuclear power plants. A similar but different argument has to do with the role of public revenues in advancing nuclear innovation. What I conclude is that there is a consistently positive relationship between innovation and social redistribution. Hence, I maintain a high degree of optimism that technology can serve the needs of the poor without hampering growth and international investment relations.

VI. References

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VII. Appendix

Table 1: Generations of Nuclear Technology

Time⁵³	Generation
1945-1965 - Generation I	Early Prototypes
1965-1995 - Generation II	Pressurized Water Reactors (PWRs)
1965-1995	CANDU
1965-1995	Boiling Water Reactors (BWRs)
1965-1995	Advanced Gas-cooled Reactors (AGRs)
1995-2030 – Generation III and III Plus	Advanced Boiling Water Reactors (ABWRs)
1995-2030	AP600
1995-2030	System 80 Plus
1995-2030	European Pressurized Reactors (EPRs)
1995-2030	Advanced CANDU Reactors (ACRs)
1995-2030	AP1000
1995-2030	Economic Simplified Boiling Water Reactors (ESBWRs)
1995-2030	APR-1400
2030-onward – Generation IV	Thermal-Very High Temperature Reactors (VHTRs)
2030-onward	Thermal-Supercritical Water Cooled Reactors (SWCRs)
2030-onward	Thermal-Molten Salt Reactors (MSRs)
2030-onward	Fast-Gas Cooled Fast Reactors (GFRs)
2030-onward	Fast-Sodium Cooled Fast Reactors (SFRs)
2030-onward	Fast-Lead Cooled Fast Reactors (LFRs)

Source: Generation IV International Forum. "Introduction to Generation IV Nuclear Energy Systems and the International Forum", *Report*, 2008.

⁵³ 1945-1965: Generation 1, 1965-1995: Generation 2, 1995-2030: Generation 3 and 3 PLUS, and 2030-onward: Generation 4.