Multi- or Internationalization of the Nuclear Fuel Cycle: Revisiting the Issue

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Abstract

The multi- or internationalization of the nuclear fuel cycle was heavily discussed in the late 1970s and early 1980s, especially with regard to the nonproliferation of nuclear weapons. The discussions mainly took place in the framework of the International Nuclear Fuel Cycle Evaluation (INFCE) conference, which started in Washington, D.C., in October 1977. In the following two years, eight international working groups evaluated the advantages and challenges of various approaches for the nuclear fuel cycle to build on models of multi- or international cooperation. It was identified that given the appropriate administrative authority, both multi-nationalization and internationalization have a potential to significantly increase the proliferation resistance of the nuclear fuel cycle, thus contributing to the objectives of the Nonproliferation Treaty (NPT), especially the spirit of Article IV. However, implementing such cooperational models also would have disadvantages, especially in the areas of political independence, transfer of technologies, and planning security of national nuclear programs. To date, only a few examples of such multinational cooperation have been implemented. In view of recent changes in global politics, technology developments in the nuclear field, and the availability of state-of-the-art safeguards equipment and procedures, it is worth reconsidering the subject and examining whether the concerns and conclusions of the INFCE working groups are still valid. It should be further considered what type of multi- and internationalization would seem both feasible and appropriate to increase the proliferation resistance of the fuel cycle. First, this paper will recall the concept and conclusions of the INFCE investigations and describe existing forms of bi- or multilateral cooperation. Next, this paper will assess the advantages and drawbacks of internationalization in terms of economics and transparency. To conclude, this paper will judge the attractiveness of the different models with regard to administrative and economic feasibility in view of nonproliferation and enhancements in relation with the NPT and the Additional Protocol (INFCIRC/540).

Introduction

Political discussions on the nonproliferation of nuclear weapons do not arise as a matter of course so much as they are triggered by external occurrences. In the 1970s, the first Indian nuclear test explosion initiated the International Nuclear Fuel Cycle Evaluation (INFCE) Conference; in the early 1990s, the discovery of Iraq's clandestine nuclear weapons program gave rise to the International Atomic Energy Agency's (IAEA) new Integrated Safeguards System. In both of these situations, the resulting discussions confirmed that ensuring compliance with the Treaty on the Nonproliferation of Nuclear Weapons (NPT) was and still is the foundation for the prevention of nuclear weapons proliferation. Recently, three events have inspired renewed discussions on the effectiveness of the nonproliferation regime: the official announcement of the Democratic Peoples Republic of Korea (DPRK) to withdraw from the NPT, the status of the nuclear program in Iran, and the Libyan renouncement of its covert military program.

Once again, NPT stands in the center of the efforts of the international community to foster the peaceful use of nuclear energy. In this regard, its importance as a universal standard was confirmed at all NPT review conferences, culminating in the 1995 Review Conference when its validity was extended indefinitely. Subsequent national and multi-national obligations, agreements, and export control mechanisms have been realized to complement the NPT, thus forming a nonproliferation network.

In light of the overwhelming support, however, it has to be understood that the nonproliferation regime is a complex framework and system consisting of individual elements within a dynamic structure. For instance, the Nuclear Suppliers Group (NSG) guidelines (currently in its sixth edition) has been one element under periodic revision. Also, in response to significant events directly related to nonproliferation policy, the international community has adopted new texts and measures to adapt to the changing global political environment. The Additional Protocol INFCIRC/540 (Corrected) is the latest example of such an adap-

tation process. It was designed in reaction to the discovery of a clandestine nuclear program in Iraq to allow the IAEA to inspect facilities and installations suspected to be, but not declared as, nuclear installations. This extended access, supported by additional information (e.g., open source), will prove to be a more and more efficient tool as it is ratified in an increasing number of signatory countries. Now, with the events in DPRK, Iran, and Libya, new ideas are emerging to strengthen the NPT regime in response to withdrawals and infringements of signatories. This development suggests that Article 4 of the NPT might have to be re-interpreted and adapted to new global nonproliferation requirements.

An important element of the NPT adaptation process has been the proposal to multi-nationalize or internationalize the nuclear fuel cycle, an idea that played a central role in the INFCE Conference. As such, this paper will begin by describing the starting position and the results of INFCE as regards the issue of multi-nationalization and internationalization of nuclear fuel cycle facilities. Next, an assessment of the different institutional models recommended by INFCE, especially in regards to non-proliferation and nuclear fuel supply assurance, will be discussed. Following, a revision of multi- or internationalization of the nuclear fuel cycle under contemporary economical and political structures will be presented. Recommendations for a possible re-assessment of Article 4 of the NPT conclude the paper.

The International Nuclear Fuel Cycle Evaluation (INFCE)

In October 1977, INFCE started in Washington, D.C., to specifically investigate opportunities for the internationalization of the nuclear fuel cycle. U.S. President Carter's original INFCE objective was to concentrate exclusively on the issue of nonproliferation of nuclear weapons. However, while organizing the conference, participants instead agreed to address the broader notion of the utilization of nuclear energy without proliferation of nuclear weapons. Nevertheless, the nonproliferation aspect remained in the focus of the analyses performed by the eight INFCE working groups, yielding the conclusions:

...that nuclear energy is expected to increase its role in meeting the world's energy needs and can and should be widely available to that end; […] and that effective measures can and should be taken to minimize the danger of the proliferation of nuclear weapons without jeopardizing energy supplies or the development of nuclear energy for peaceful purposes.

Additionally, to counter the danger of nuclear weapons proliferation in connection with the peaceful uses of nuclear energy, INFCE highlighted a number of universal measures: institutional measures, technical measures, and improvement and further development of IAEA safeguards. For the purpose of this analytical paper, only institutional measures will be investigated.

To understand the impact such measures have on nonproliferation, one has to realize that nuclear fuel supply assurance as well as waste management and storage solutions are essential to the economic feasibility and sustainability of a nuclear fuel cycle. Accordingly, an incentive for states to develop their own enrichment and reprocessing capabilities is the minimized dependence on international fuel supply; however, once a state has its own enrichment and reprocessing capabilities, it cannot be ruled out that these technologies will be used to create weapons-grade materials. This poses an exceptional proliferation risk considering that any signatory to the NPT has the right to withdraw from the treaty. Guaranteeing fuel supply and both waste management and storage services through institutional arrangements will reduce the incentive to develop national enrichment, reprocessing, and management capabilities, thus reducing the proliferation risk.

The term *institutional arrangements* was broadly interpreted in INFCE. It includes a variety of provisions that can be foreseen either by government agencies or by private entities. However, the effectiveness of any institutional arrangement applied to the nuclear fuel cycle has to be assessed in the light of both the non-proliferation of sensitive nuclear technologies and the assurance of supply. In detail, such institutional arrangements comprise commercial agreements, technical support programs, international studies, nonproliferation agreements, supply/delivery agreements, and international and multi-national institutions.

Institutional measures in the form of multi- or international cooperation prove to be attractive models. Within such cooperative relationships, trade arrangements and treaties can be viewed as tools of a nonproliferation policy. However, the successful implementation of such models is highly dependent on mechanisms to credibly guarantee an assured supply of nuclear fuel. For waste management and storage solutions, the proliferation risk is less imminent because there is less incentive for a country to develop its own capacities; furthermore, the development does not involve technologies essential to nuclear weapons development.

On the other hand, some states interested in utilizing nuclear energy in the future will not be prepared to address the full scope of requirements to sustain the infrastructure of a complete fuel cycle. This perceived technical inability might thus discourage them from exploring nuclear programs at all. Therefore, institutional mechanisms such as multi- or international cooperations that credibly provide front- and back-end solutions can help to foster the peaceful use of nuclear energy. The institutional models discussed by INFCE apply to the following front- and back-end services:

- Uranium enrichment
- Spent fuel reprocessing
- Plutonium storage
- Transport and storage of spent fuel

In the field of uranium enrichment, INFCE discussed institutional arrangements that foresee multi- or international control, with government participation, of the facility technologies and

nuclear materials. It was stated that institutional measures such as classification and export controls of sensitive components and technologies were already practiced and that multi-national facilities already existed. In particular, such institutional arrangements are capable of preventing proliferation scenarios that are not covered by international safeguards agreements (e.g., in connection with the transfer of nuclear technologies).

In the field of spent fuel reprocessing, primary types of multi-national arrangements are reprocessing services guaranteed by countries with large reprocessing plants. For the more distant future, INFCE discussed the possibilities of multinational enterprises in the frame of regional fuel cycle centers. However, INFCE not only expected substantial obstacles in the areas of both plant operation and national legislation, but also practical difficulties in connection with the establishment of such institutions.

International plutonium storage facilities are recognized to have the potential to reduce proliferation risks by pooling sensitive materials in a limited number of storage facilities under safeguards. Thus, INFCE considered such an institutional measure an important tool to secure and safeguard excess plutonium and to strengthen the nonproliferation system.

In the field of transport and storage of spent fuel, INFCE suggested to further investigate the extent to which multi- or international cooperations could support economical and management infrastructures of spent fuel. Furthermore, it was stated that multi-national and international repositories for the final disposal of spent fuel can possibly be advantageous to nonproliferation and the economical feasibility of nuclear energy.

In their discussions, the eight INFCE working groups addressed different institutional models that could be the basis for an international cooperation in the nuclear fuel cycle, and, to their best knowledge, highlighted the advantages and disadvantages. Each working group's findings emphasized that multinationalization has the potential to limit the number of sensitive facilities. Such a limit would have a positive impact on both nonproliferation and economical operation of the plants. However, considerable drawbacks such as the risk of proliferation of sensitive know-how were highlighted. Important questions, especially those related to the host country of front- and back-end services, remained to be answered, such as:

- What countries will host such facilities?
- How will the responsibilities of the host country be defined in regards to safety, physical protection, and environmental protection while considering legitimate interests and influence of the foreign shareholders?
- What solutions can be implemented to prevent the host country from jeopardizing the assurance of supply for foreign shareholders that invested into a facility located outside their national borders?

Assessment of Different Institutional Models

The INFCE investigations proved that there is a large variety of possibilities for cooperation in the nuclear area. The simplest form–a purely national enterprise–would involve a cooperation of all intra-national private entities as well as governmental bodies to comprehensively address a nation's nuclear energy needs. However, since this approach still holds the incentive to develop a country's own fuel services, it does not change the proliferation risk related to that country. To move from this purely national enterprise towards multi- or internationalization, a first step is to solicit the financial participation of other states in facilities not located within their own national borders. Further broadening the scope of cooperation models includes facilities operated by international staff or management, multi-national enterprises that renounce sovereign rights to different extents, and, finally, international organizations on extraterritorial ground or regional fuel cycle centers.

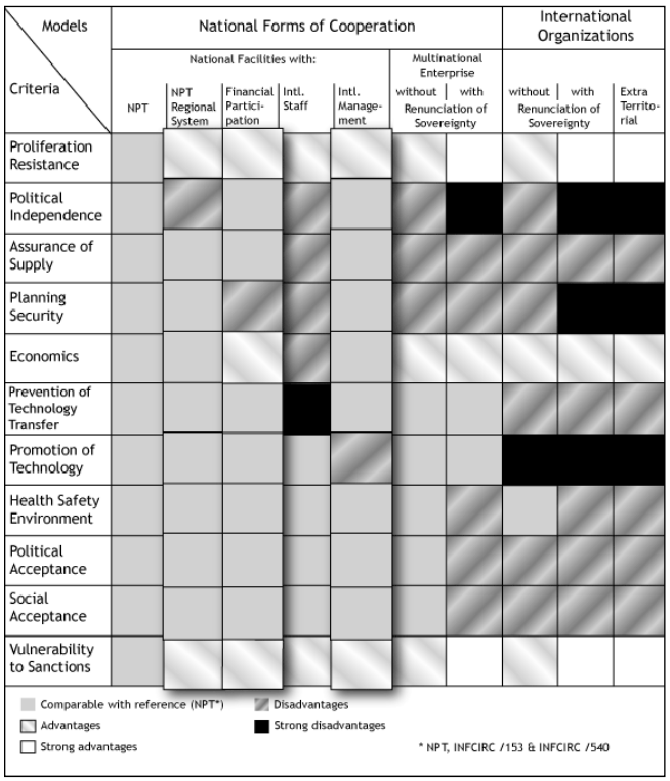
Apart from supporting nonproliferation, such cooperative models have to be assessed in terms of their abilities to ensure nuclear fuel supply. However, when implementing multi-national facilities in practice, other criteria have to be taken into account, such as health, safety, environmental protection, and technology transfer, as well as social and political acceptance in the host state. These criteria might turn out to be negatively correlated to the increase in proliferation resistance, thus reducing the expected utility of implementing institutional models. Also, additional proliferation resistance is obtained by increasing dependencies under international law, especially when states participate in international forms of cooperation. While multilateral agreements on contractual basis can mitigate the complexity of such cooperation, international models have to credibly threaten sanctions to signatories that decide to break their commitments by denying fuel supply or waste management services to other participants.

In an international institutional scenario, host states face a higher proliferation threshold, as multi-nationalization limits the host government's legal possibilities to divert materials owned by multiple parties. Misuse could be detected sooner and more easily as the application of international safeguards would be more effective. It would also be possible for participating states or the international safeguards community to impose sanctions if international obligations were violated with facilities or materials being misused. On the other hand, it has to be taken into account that there may be problems arising from legal issues related to the integrity of the national sovereignty of the host country, which could detract from the advantages of such solutions.

Figure 1 analyzes how various aspects of institutional solutions bear upon the multi- or internationalization of the nuclear fuel cycle. From the assessment matrix, it may be concluded that when prioritizing the proliferation resistance criterion, a multinational enterprise with a certain degree of renunciation of sovereign rights on the part of the host state represents a favorable

solution. The disadvantages are represented in reduced political independence as well as in reduced acceptance of the renunciation of sovereign rights in the host state. Also, safety, environmental considerations, and public and social acceptance considerations counterbalance the advantages in proliferation resistance. For these reasons, it might be very difficult to realize this institutional model. However, if the proliferation resistance criterion is not attributed the highest priority, the preferred models could be identified as a national facility located in a state that is party both to the NPT and to a treaty similar to the Euratom Treaty. In such balanced scenarios (highlighted columns in Figure 1), nonproliferation advantages are realized while detrimental factors only mildly influence the feasibility of the models.

Figure 1: Assessment Matrix for Institutional Models



Not all institutional measures for front- and back-end scenarios can be treated equally. In particular, international mechanisms are less appropriate to apply to production facilities for uranium enrichment, spent fuel reprocessing, or fuel fabrication, as such measures encounter a number of financial, technical, and R&D-political difficulties. In contrast, international organizations can be more easily realized in connection with storage facilities for fissionable materials and spent fuel; the storage of nuclear materials does not involve the application of sensitive technologies like fuel enrichment or reprocessing do.

Multi- or Internationalization Revisited

The INFCE results showed that, under certain conditions, multinational or international institutional models have a limited potential for application in the nuclear fuel cycle. However, the topic of assurance of supply, which dominated the INFCE discussions along with nonproliferation considerations, no longer holds the same relevance because enrichment services are now provided by a few suppliers, and there has been no shortage of *capacities*.

Today, as has been illustrated by the recent proliferation cases, the real proliferation concerns rest with the export of sensitive technology such as uranium enrichment using gas centrifuges. In addition, with the trend leaning toward privatization of previously nationally owned enterprises, profitability of electricity generation using nuclear energy has gained considerable importance. In this respect, private enterprises, dependent on both their shareholders' decisions and quotation agencies' reports, cannot afford to cover proliferation activities, especially while under constant media scrutiny.

To properly apply INFCE recommendations to foster the peaceful use of nuclear power while enhancing proliferation resistance and reducing the risk of illicit technology transfers, the economic dependability of nuclear energy in terms of assurance of supply and waste management needs to be highlighted. Having reliably available front- and back-end components (i.e., fuel enrichment, waste management, or final storage) is the only way to maintain a nuclear fuel cycle that can pose a valid, competitive alternative to other energy sources.

Also, it is important to understand how the global situation in regard to the use of nuclear energy has changed since the INFCE conference. In the timeframe of the 1970s and 1980s, energy markets were generally directed by governmental monopolies, and nuclear fuel programs were inspired by assumptions on national energy demands only. This situation implied each nation interested in using nuclear power had to develop its own solutions not only for the actual operation of reactors but also for sustaining the front- and back-end of the fuel cycle. This precisely reflects the spirit of Article 4 of the NPT that allows for signatory states to ask for assistance from the international community to develop such solutions in exchange for committing to safeguards.

In this respect, the INFCE recommendations were as revolutionary as they were anachronistic. Institutional mechanisms, such as multi- or international cooperations, were not backed by liberal energy markets driven by international companies with a global business approach. Thus, the implementation of such institutional measures could be prepared by international agreements, but not realized in a competitively functioning global marketplace.

Times, however, have changed. Today, energy markets are in the process of being privatized, and business players have started operating as global entities. Therefore, the following general trends can be identified as part of an international process that leads to more transparency and contributes to nonproliferation efforts:

Sustainable Development

With the depletion of fossil fuel resources (e.g., coal, gas, and oil), ongoing discussions on the general energy supply situation and calculations on meeting future energy demands address the peaceful use of nuclear energy more in economical, ecological, and socio-political terms than with nonproliferation considerations. Even if the nonproliferation of materials and technologies can be assured, nuclear power as a sustainable energy source can only be implemented if the expectations of the public regarding both safety and proliferation resistance can be sufficiently guaranteed.

Programs such as the U.S.-launched Generation IV International Forum (GIF) and the IAEA International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) take these considerations into account.

GIF, for instance, is designed to foster international cooperation in hopes of improving the attractiveness of future nuclear reactors, taking into account nuclear safety, economics, sustainable development aspects (e.g., minimization of waste, or a health issue), and nonproliferation issues. In the context of GIF, proliferation resistance is defined as a comprehensive approach involving technical (intrinsic) as well as institutional and political (extrinsic) measures. Six models have been selected for investigation. The Very High Temperature Reactor (VHTR) technology, for instance, should prove to be of interest from the proliferation resistance standpoint.

Liberalization of Energy Markets and Globalization in the Private Sector

Multi-nationalization is a trend that is nourished by the globalization of markets in general and the liberalization of the energy market in particular. In the field of nuclear energy, this trend is reflected in the establishment of AREVA, addressing the whole fuel cycle; British Nuclear Fuels (BNFL), addressing waste management and reprocessing services; as well as Urenco, addressing uranium enrichment services with plants located in three European countries.

Similar trends can be identified in the field of nuclear power plant design and construction where Framatome and Siemens entered into a partnership before joining AREVA. As the liberalization of markets progresses on a global scale, the competition among different primary energy carriers and energy technologies will lead to further merging of companies and will further enhance the process of multi-nationalization within the private sector.

Transfer of Sensitive Nuclear Technology

The most recent examples of undeclared activities in the field of uranium enrichment in Iran and Libya (although the gas centrifuge technologies that were used had been transferred from Pakistan) have demonstrated that the proliferation of sensitive technologies are difficult to inhibit, given the dissemination of knowledge and banalization of large parts of the technology. The improvement, standardization, and strict application of export controls, as well as the possibilities provided by international safeguards in combination with the Additional Protocol to detect undeclared nuclear activities will help prevent the construction of clandestine facilities. In addition, fostering the implementation of multi-national cooperation or multi-national applications will facilitate a worldwide reduction of commercial nuclear facilities in the sectors of uranium enrichment and spent fuel reprocessing; this, in turn, will help to reduce technology transfers that might be used for weapons programs, for instance, after a signatory withdraws from the NPT.

Multi-National Facilities and Effectiveness of Safeguards

As a complement to INFCIRC/153 (Corrected), the INFCIRC/540 does not represent a declared material-oriented and facility-related system but bases its safeguards implementation and evaluation on state-level information. The information sources employed are manifold and comprise, among others, safeguards inspections information on research and development, cooperative or export activities, as well as open source information. In the context of INFCIRC/540, the responsibility of a country using nuclear power for peaceful purposes to transparently share information with the safeguards community is of utmost importance.

The concept of multi-national facilities is able to support this transparency to a considerable degree and to further facilitate the verification of declared nuclear materials or activities. This is also important under the consideration of applying safeguards in efficient cost structures because fewer facilities have to be visited by international safeguards inspectors. Furthermore, the implementation of multi-national facilities will facilitate the swift investigation and resolution of possible inconsistencies or anomalies in a host country. Every shareholder country has an invested interest in preventing and uncovering possible diversion efforts because they might endanger their fuel cycle related services.

The migration of safeguards surveillance technologies from analog to digital systems, as well as the implementation of advanced encryption and authentication algorithms provides another tool that can support transparent monitoring of multi- or international facilities. Generated surveillance data can be shared by signatory states and individually reviewed for compliance verification purposes. Since this verification process is essential for the success of multi- or international models, the application of data-sharing safeguards equipment should be encouraged.

A state developing full nuclear fuel cycles that include fuel enrichment and reprocessing capabilities must commit to long-term research and development projects that require extensive planning and funding. If multi- or international front- and back-end cooperations can be successfully implemented (i.e., the availability of fuel supply and waste management services can be sufficiently guaranteed, and nonproliferation concerns can be transparently addressed), individual nuclear programs should no longer hold incentives. Should countries still pursue their own

research, this pursuit could be considered an indicator that interests other than economic sustainability of nuclear energy are predominant drivers of such national programs.

A New Assessment of NPT Article 4

The central question is: What is the immediate result of the analyses of this paper in regards to the practical interpretation of Article 4 of the NPT?

Primarily, the basic right of states to utilize nuclear energy for peaceful purposes is not to be doubted. This basic right is an essential part of both the NPT and any well balanced system to foster the use of nuclear energy and safeguards, as well as to usher in the final nuclear disarmament of nuclear weapons states. This established norm of the NPT must not be jeopardized.

However, since the NPT was signed in 1968, the international community has experienced significant changes in the political and economical environment that are not accounted for in the spirit in which the NPT was written. The peaceful use of nuclear energy has to be evaluated not only with nonproliferation considerations but also in ecological, economical, and political terms. These evaluation patterns will be the basis of future innovative nuclear technologies that will be developed with the aim of ensuring proliferation resistance and reactor safety. Also, for these future concepts, economical requirements have to be met in order to ensure that nuclear energy is competitive with other energy sources.

For economic reasons and for reasons of competitiveness, the need for uranium enrichment and spent fuel reprocessing facilities is questionable in countries with small- or medium-sized nuclear programs if multi-national enterprises are able to reliably provide services on a global scale and to guarantee long-term services for international partners. This statement is valid not only in the nuclear energy sector but also in other areas involving sensitive technologies.

The INFCE discussions concluded that the institutional framework for multi- or international cooperations can generally be implemented. The globalization and liberalization of energy markets now provide an economic infrastructure that can partly respond to the need to internationalize the fuel cycle. Industry can consider strengthening the contractual basis for guaranteeing a supply of foreign customers, but this preferably will be done in the framework of long-term contracts and only within the limits of the state's guarantee to provide its authorization for export.

Negotiated contracts could include provisions that institutionalize the IAEA as the overseeing agency with the acknowledged duty of determining if a signatory country meets the safety requirements to receive fuel supplies. If the situation in a country is deemed unsatisfactory, the respective country's assured fuel supply could be suspended, and the provider of fuel could be compensated by the international community.

In the uranium enrichment or reprocessing sectors, financial participation in a multi-national private enterprise can represent a realistic solution that has in some instances already been implemented. In the waste management sector, different multi-national approaches under international safeguards are conceivable, but if an international depository is to be opened, it should be identified as such by the IAEA. The IAEA's identification should take into consideration its safety features, safeguards applicability, and its openness to quantities of waste coming from countries where no such disposal program is reasonably envisioned and regardless of the fabricated fuel's country of origin.

Recent cases or threats of proliferation have not stemmed from the diversion of civil trade that was placed under IAEA safeguards. Neither civil plutonium nor LEU that was under safeguards has been used or is thought to have been used (except for the specific case of DPRK). Instead, the main nonproliferation threats have originated from the use of sensitive technologies acquired by illicit or autarkical means. Thus, reinforcing the implementation of export control regulations worldwide and extending the commitment not to transfer these technologies can help address these types of threats.

The nuclear industry is willing to contribute to new ideas and to implement new contractual models that help avoid the dissemination of sensitive technologies in too many countries, thus supporting the task of the international safeguards community by concentrating their efforts in a few countries. For this purpose, Article 4 of the NPT indeed needs to be re-interpreted. Rather than fostering the transfer of sensitive technologies and materials, the international community should encourage shared comprehensive solutions that allow all signatories to the treaty to sustain reliable nuclear fuel cycles.

Literature

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