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Market competition in the nuclear industry
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Market competition in the nuclear industry*

Nuclear Energy Agency (NEA)**

Abstract
Nuclear power plants require a wide variety of specialised equipment, materials and services for their construction, operation and fuelling. There has been much consolidation and retrenchment in the nuclear industry since the 1980s, with the emergence of some large global nuclear companies. Electricity market liberalisation in many OECD countries has meanwhile placed nuclear plant operators under increased competitive pressure. These structural changes in both the producer and consumer sides of the nuclear industry have had implications for the level of competition in the nuclear engineering and fuel cycle markets. With renewed expansion of nuclear power now anticipated, this study examines competition in the major nuclear industry sectors at present, and how this may change with a significant upturn in demand.

Keywords
Nuclear power, nuclear companies, electricity, competition, nuclear engineering, demand.

Concurrence du marché dans l'industrie nucléaire

Résumé
Les centrales nucléaires nécessitent d'une grande variété d'équipements, matériaux et services pour leur construction, exploitation et ravitaillement. Il y a eu beaucoup de consolidation et de retranchement dans l'industrie nucléaire depuis les années 1980, avec l'apparition de quelques grandes compagnies nucléaires au niveau mondial. La libéralisation du marché de l'électricité dans de nombreux pays de l'OCDE a entre-temps mis les exploitants d'installations nucléaires sous une pression concurrentielle accrue. Ces changements structurels dans les producteurs et les consommateurs de l'industrie nucléaire ont eu des implications dans le niveau de concurrence dans les marchés de l'ingénierie nucléaire et du cycle du combustible. Grâce à une nouvelle expansion de l'énergie nucléaire prévoit maintenant, cette étude examine la concurrence dans les majeurs secteurs de l'industrie nucléaire en ce moment, et comment cela pourrait changer avec une amélioration significative de la demande.

Mots-clefs
Énergie nucléaire, industrie nucléaire, électricité, concurrence, ingénierie nucléaire, demande.

* OECD (2008), Market Competition in the Nuclear Industry, p. 7-23, p. 111-120

** The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full member. NEA membership today consists of 28 OECD member countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, the Republic of Korea, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities also takes part in the work of the Agency.The mission of the NEA is: to assist its member countries in maintaining and further developing, through international cooperation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as; to provide authoritative assessments and to forge common understandings on key issues as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development. Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries. In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field, Paris, France. Web: www.nea.fr

Competencia en el mercado de la industria nuclear

Resumen
Las centrales nucleares requieren una gran variedad de equipos especializados, materiales y servicios para su construcción, operación y abastecimiento de combustible. Desde la década de 1980, ha habido una gran consolidación y reducción en las industrias nucleares con la aparición de grandes empresas nucleares a nivel mundial. La liberalización del mercado de la electricidad en muchos países de la OCDE, ha entretanto colocado a los operadores de estas plantas bajo una creciente presión competitiva. Los cambios estructurales tanto del lado del productor como del consumidor han repercutido en el nivel de competencia de los mercados de la ingeniería nuclear y de los ciclos de combustible. Con la renovada expansión de la energía nuclear ahora prevista, este estudio examina la competencia en los principales sectores de la industria nuclear en la actualidad, y cómo esto podría cambiar con una mejora significativa en la demanda.

Palabras claves
Energía nuclear, empresas nucleares, electricidad, competencia, ingeniería nuclear, demanda.

Foreword

The present and future owners of nuclear power plants require a wide variety of specialised equipment, materials and services to build, operate and fuel their plants. Low demand in many nuclear industry sectors since the 1980s has resulted in consolidation and retrenchment, with the emergence of some large global nuclear companies. Meanwhile, electricity market liberalisation in many OECD countries has changed the environment in which nuclear plants operate, putting them under competitive pressures.

These important structural changes in both the producer and consumer sides of the nuclear fuel and nuclear reactor design and engineering markets have had implications for the level of competition in the nuclear industry. This study examines market competition in the supply of goods, materials and services for the design, engineering and construction of new nuclear plants, for the entire nuclear fuel cycle, and for the maintenance and upgrading of existing plants. It does this by assessing a set of ten market characteristics selected to act as broad indicators of competitiveness, including the market shares of major participants.

With renewed expansion of nuclear power expected over the next decade and beyond, to the extent possible the study considers how the level of competition may change with a significant upturn in demand. It also looks at the potential implications for market competition of proposed multilateral fuel supply arrangements currently under discussion.

Acknowledgements

The study was carried out by an ad hoc group of experts nominated by NEA member countries, listed in the Appendix. The group was co-chaired by Dr. Koji Nagano of Japan and Mr. David Shropshire of the United States. The Secretariat would like to acknowledge the important contribution made by each member of the expert group. Thanks are also due to Professor Jan Horst Keppler of *Université Paris Dauphine*, who provided valuable advice on the methodology for assessing market competition.

Executive summary

The nuclear industry provides a wide variety of specialised nuclear equipment, materials and services to support the design, construction, operation and fuelling of nuclear power plants (NPPs). This includes the supply of NPPs themselves, the range of materials and services required in the nuclear fuel cycle, and the services and equipment needed for maintenance and upgrading. The markets to provide these have changed substantially as they have evolved from the government-led early stages of the nuclear industry, and most sectors now operate as competitive commercial markets.

There has been much consolidation and retrenchment in the nuclear industry since the 1980s in response to generally low demand, which has resulted in the emergence of a small number of large global players in some sectors. This partly reflects special factors in the nuclear industry, but also the more general trend towards globalisation of major industrial activities. Meanwhile, the liberalisation of electricity markets in many OECD countries has changed the business environment for NPP owners/operators. Electricity utilities have been exposed to increased competition, requiring them to improve their business performance and making them more cost-conscious.

There have thus been major structural changes on both the producer and consumer sides of the nuclear markets since the major expansion of nuclear power in the 1970s. The Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle of the OECD Nuclear Energy Agency (NEA) established the Ad hoc Expert Group on Market Competition in the Nuclear Industry to examine how the major market sectors are performing in present market conditions and, with renewed expansion of nuclear power expected over the coming years, how these markets can be expected to change with a significant upturn in demand. The study also considered the potential implications for market competition of the broad types of multilateral assured fuel supply arrangements which have been proposed by several governments.

In carrying out its study, the expert group kept in mind that there are some areas of nuclear activity where competition is necessarily limited or even absent. This includes many research and development activities, especially those with a longer term goal, where international co-operation and government support are necessary until new technologies are ready for commercialisation. Within existing commercial sectors, certain limitations also necessarily exist, notably non-proliferation controls on sensitive materials, equipment and technologies.

Furthermore, nuclear power involves very large investments in complex plant and equipment, and requires a high level of specialised expertise. This often results in long-term relationships between suppliers and customers, who work together to ensure that plants operate safely and efficiently, and that improvements and upgrades can be made effectively. The expert group noted that in nuclear markets, quality and reliability are often at least as important to customers as prices.

Assessing the competitiveness of markets

In the absence of detailed statistical information about each market sector, to assist the expert group in making objective assessments it was decided to consider a set of market characteristics which could act as indicators of competitiveness. Although the assessment of each indicator involved a degree of subjective judgement, taken together they provided a useful overall impression of the effectiveness of competition in each sector. These indicators were:

- Market shares of major participants.
- Degree of vertical integration.
- Proportion of long-term contracts.
- Barriers to entry.
- Transaction costs and market segmentation.
- Product differentiation.
- Balance of capacity and demand.
- Market alliances and supplier co-operation.
- Public goods aspects.
- Trade barriers and restrictions.

Where possible, market shares were used to calculate the Herfindahl-Hirschman Index (HHI) for the market sector, defined as the sum of the squares of the percentage market shares of all market participants. If the value of HHI is greater than 1 800 this is often taken as a sign that a market may be overconcentrated.

Main findings for each major market sector

Design, engineering and construction of NPPs

This sector appears poised for a major expansion in the coming decade and beyond. Despite the prolonged market depression since the 1980s and the consolidation which resulted, the remaining NPP vendors have continued to develop their designs and are now offering considerably improved products. At least in the major markets, where there is the potential for a series of orders, there is likely to be strong competition between four or five vendors. Despite some market distortions, notably where vendors dominate their home markets, a global market with several independent and competing vendors has emerged which provides a genuine choice of supplier to potential customers. However, different regulatory requirements for NPP designs between countries, which can lead to significant up-front costs for vendors, may effectively limit the choices available, particularly in smaller markets.

In the longer term, there is the prospect of the emergence of additional important NPP vendors. The most probable of these are those who have benefited from technology transfer deals with the existing vendors, and have gone on to develop the technology further themselves and eventually reach the status of independent vendors able to offer their distinct designs on the global market. In particular, such companies may well emerge in Korea and China. New vendors based on more innovative reactor designs developed independently of the existing vendors may also emerge, but this is less certain and is likely to take longer.

Uranium supply

A significant number of new uranium production facilities is expected to enter operation over the coming years in response to rising demand. Many of these will be owned by new entrants or smaller producers with growing production. Although some consolidation is likely to occur, the trend is expected to be towards reduced market concentration. However, the possibility of a merger of two of the major producers could be a cause for concern if it led to the merged company controlling a very large share of global production. Trade restrictions on uranium imports into the United States and the European Union since the early 1990s have affected market competition. However, increased demand and the reduced availability of supplies from existing stockpiles is likely to limit the practical impact of these restrictions on the market, even if the measures themselves remain in force.

UF_6 conversion services

There are effectively only three major suppliers of UF_6 conversion services to the global market, with a fourth supplier which is mainly limited to providing uranium, conversion and enrichment as a package. From a market competition perspective, this indicates that the market is more concentrated than would be desirable. However, the role of conversion plants as the main storage locations and clearing houses of the uranium market may mean that it is more convenient for market participants if there is a relatively limited number of sites. Together with the fact that conversion represents only a small fraction (around 5%) of the total cost of nuclear fuel, this means that new conversion facilities on new sites may have difficulty in establishing themselves. Present expansion plans indicate that the existing major suppliers will expand their capacity as required and little change can be expected in the degree of market concentration.

Uranium enrichment services

Enrichment technology is among the most sensitive in terms of nonproliferation, which means that it is possessed by a limited number of countries, and is entrusted by governments to only a small number of commercial operators; this inevitably limits market competition in this sector. However, the enrichment industry is undergoing major changes which will re-shape it over the next ten years and beyond. The remaining older gas diffusion plants in France and the United States will be replaced by new centrifuge plants, while there is also the prospect of laser enrichment technology being commercialised. There will be at least two and possibly as many as four new enrichment plants in the United States by 2015, each operated independently by competing suppliers. The large enrichment capacity in Russia is also expected to play a larger role in the international market. These developments are likely to lead to shifts in the market shares of the existing suppliers.

Fuel fabrication services

Unlike other fuel cycle services, fuel fabrication is essentially a bespoke service to prepare fuel assemblies to the exact requirements of each NPP. For a new NPP, fuel is initially supplied by the NPP vendor. Only later in the NPP's operating life does the possibility of choosing between competing suppliers open up. Furthermore, some NPP operators may not consider that the commercial risk involved in changing suppliers is justified by the potential savings on fuel costs. Nevertheless, significant competition does exist in the fuel fabrication market, and for NPPs of more common designs there may be a choice of up to three fabricators. However, the fuel fabrication market has consolidated over recent years, as the main NPP vendors have consolidated. It now appears that the market for fuel fabrication is more concentrated than would be desirable. For some market sub-sectors there is effectively no competition.

For new NPPs, initial fuel loads will inevitably be supplied by the plant vendors, who will add new capacity when and where necessary. Where a large nuclear programme is undertaken, additional capacity may be provided by licensing the fuel design to a local fabrication plant. However, the development of a competitive market for these new fuel designs will require alternative suppliers to emerge. This is a matter to which purchasers of NPPs will need to give due consideration when making their choice of reactor technology. Experience has shown that one way to ensure a choice of fuel supplier is to choose a NPP design which is being built in significant numbers, as in time such designs are likely to be better served by alternative fabricators.

Back-end of the nuclear fuel cycle

Much of the capacity of the limited number of spent fuel reprocessing plants is devoted to domestic arisings of spent fuel, but some also reprocess spent fuel from other countries under contracts with foreign utilities. Thus a limited international market does exist, but this has been declining in recent years. With the prospect of significant future expansion of nuclear power, the potential for spent fuel reprocessing and recycling is attracting renewed interest. However, reprocessing technology is highly sensitive from a non-proliferation perspective. Reprocessing is likely to be restricted to a small number of countries, or be subject to multilateral control. Its wider use is also likely to depend on the adoption of advanced reactor designs which allow full advantage to be taken of the recycled materials. The commercialisation of such designs is not expected to occur until well after 2020.

Plutonium separated in existing reprocessing plants can be used to fabricate mixed-oxide (MOX) fuel for use in some existing light water reactors (LWRs). There are presently two commercial plants in operation, in the United Kingdom and France. Fabricated fuel has been supplied to several European countries and to Japan. This has so far been a limited market, driven mainly by the desire of the utilities concerned to utilise their plutonium. MOX fuel fabrication is thus tied to the future of commercial reprocessing, and in the longer term to the deployment of advanced reactor types using fuel containing recycled materials.

In general, utilities remain responsible for the management of radioactive waste arising in their plants, at least until it is handed over to a national authority or agency responsible for its disposal. A similar situation exists for the decommissioning of disused facilities and the waste generated during such activities. Thus, commercial activity in these sectors is generally limited to the provision of services, technology and equipment. Many specialized companies are involved, as well as many of the main nuclear industry companies. Overall, there is considerable competition and innovation in the provision of services, technology and equipment for radioactive waste management and decommissioning.

Services for maintenance and upgrading of existing NPPs

With the lack of orders for new NPPs in recent years, reactor vendors and other nuclear engineering companies have been increasingly reliant on the business of maintaining, backfitting and upgrading the existing reactor fleets. With life extensions now planned for a large number of existing NPPs, the demand for major upgrading projects is likely to remain high. At present, there appears to be a good balance between capacity and demand in this sector with a good degree of competition in most sub-sectors of what is a multi-faceted market. However, if there is a significant increase in orders for new NPPs in the coming years this situation could change, as construction of new plants will often involve the same companies. It could potentially become more difficult to find competing suppliers able to undertake routine maintenance tasks and larger upgrading projects in a timely fashion.

Overall assessment of market competition

The expert group's analysis shows that the most concentrated nuclear industry market sectors are enrichment and fuel fabrication, with in each case one supplier having over 30% of the market and others in the 20% to 30% range. Reprocessing is also concentrated, although this is a smaller and less well-developed market. Overall, however, no sector in the front-end of the fuel cycle has a single company with an overwhelming dominance, with each having at least four competing suppliers. No indication was found from presently available information that market shares of leading suppliers are likely to increase significantly as the sectors expand over the next ten years. Indeed, in some sectors, notably uranium supply, it appears that the market may become less concentrated over the coming years.

In the market for new NPPs, it is difficult to assess future market shares as this will depend on the relative success of the vendors in winning orders. However, in most regions there is significant competition between at least three or four suppliers. In this, the NPP market compares favourably with certain other engineering-based industries with complex high-technology products, notably the aerospace industry. Early indications are that each major NPP vendor will win a significant share of new orders over the next decade. The future market for fuel fabrication services will to a large extent also be shaped by the market for new NPPs.

Several major nuclear companies have a significant share of more than one sector, i.e. there is a degree of vertical integration across several of the market sectors. Insofar as such companies supply nuclear equipment, services and materials as a package, this may lead to a reduction in competition in some sectors. In particular, some fuel cycle companies (which are not also NPP vendors) may be at a disadvantage, as might NPP vendors which cannot offer the full range of fuel cycle services. Such comprehensive arrangements are so far rare, but in future some customers may prefer the perceived security of receiving a complete package of services from a single large supplier. If comprehensive provision is preferred by some customers, it is likely that an increasing number of companies will try to position themselves to meet this requirement.

Implications of proposed multilateral fuel supply arrangements

With an increasing number of countries considering launching a nuclear power programme in the future, the issue of multilateral assured fuel supply arrangements is being discussed by governments in international forums, notably under an initiative launched by the International Atomic Energy Agency (IAEA). It is beyond the scope of this study to consider or take a view on the benefits of the proposed arrangements for addressing security of supply or proliferation concerns. However, the expert group did consider in a general way the potential implications for market competition of such arrangements, while keeping in mind that many of the details of the proposed arrangements have yet to be developed.

The study considered the proposed arrangements in three broad categories, which involve assurances being provided to consumers in the following ways:

- Stockpiles or fuel banks controlled by an independent multilateral agency.
- Fuel supply guarantees provided by multiple supplier countries.
- Fuel cycle facilities under multilateral control.

Arrangements involving the establishment of one or more fuel banks would be expected to closely resemble current market conditions, and would not be expected to have a significant impact on international nuclear markets. However, they could potentially serve to protect the market shares of existing suppliers and to discourage new market entrants in some sectors. On the other hand, some existing trade restrictions could be removed, giving suppliers access to additional customers.

Where assurances would be provided by supplier countries or by the establishment of multilateral fuel cycle centres, this could result in nuclear infrastructure remaining concentrated in a limited number of countries, requiring consumers to enter long-term partnerships with suppliers or participate in multilateral centres. Such ties could reduce the ability to choose among competing suppliers in the market, and could also lead to more vertical integration, particularly if orders for new NPPs included the leasing of nuclear fuel. However, such arrangements could also be structured to encourage the establishment of additional fuel cycle facilities under independent commercial control, which could add to overall supply and increase competition.

Key findings and recommendations

- Competitive markets for the supply of goods and services for the construction, operation and fuelling of nuclear power plants are an important factor in ensuring the overall competitiveness of nuclear power, thus helping its benefits to be more widely spread. Governments should encourage and support competition in these markets, and actively seek to prevent concentration of market power where it unduly limits competition.

- An important policy aim of some national nuclear programmes is the development of a domestic nuclear capability. This may necessarily involve some protection of infant industries, with national investment focused on a single supplier to avoid duplication. However, care should be taken not to permanently exclude competitive pressures, which should be allowed to strengthen as market and industrial sectors mature.
- While longer term development and demonstration of new nuclear power technologies may require government support and funding, competition is a great spur to innovation and technological development, helping to improve the products and services available. As fledgling technologies mature and reach the stage of commercial deployment, they should be increasingly subject to the competitive pressures which will allow them to achieve their full potential.
- Strong non-proliferation controls on sensitive nuclear materials and technologies are vital for the existence of open and competitive global markets in the nuclear industry. Such controls will necessarily involve some market restrictions and limitations. Nevertheless, non-proliferation controls are consistent with the development of new capacities by competing suppliers to meet the growing requirements of nuclear programmes around the world.
- Other restrictions and tariffs on international trade in goods and services for nuclear power plants can unnecessarily add to the costs of nuclear power. Governments should aim to eliminate or reduce them to the extent possible.
- The best assurance of supply of nuclear fuel and other essential goods and services to NPPs worldwide is the existence of a geographically diverse range of independent suppliers competing on commercial terms in all market sectors. Governments should seek to create the necessary legal and regulatory frameworks in which such a situation can develop. Furthermore, the harmonisation of such frameworks between countries, especially for the approval of new NPP designs, would increase customer choice and enhance competition in nuclear markets.

Introduction

Designing, building, operating and fuelling nuclear power plants requires their owners/operators to procure a variety of specialised nuclear equipment, materials and services. The markets to provide these have changed substantially over their history as they have evolved from the government-led early stages of the nuclear industry.

Since the 1980s, there has been much consolidation and retrenchment in the nuclear industry, which has resulted in the emergence of a small number of large global players in some sectors. This partly reflects special factors in the nuclear industry, but also the more general trend towards globalisation of major industrial activities. Further consolidation and restructuring may take place in response to market changes.

Meanwhile, electricity market deregulation in many OECD countries has changed the business environment for NPP owners/operators. Utilities that were once state-owned or price-regulated monopolies have been exposed to competition, requiring them to improve their business performance at all levels. This has made them more cost-conscious, while freeing them from some government-imposed restraints.

Thus, there have been major structural changes in both the producer and consumer sides of the nuclear fuel and nuclear design and engineering markets since the major expansion of nuclear power in the 1970s. The Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle of the OECD Nuclear Energy Agency (NEA) decided to establish an ad hoc expert group to examine how the major market sectors are performing at present and, with renewed expansion of nuclear power expected over the coming years, how these markets can be expected to change with a significant upturn in demand.

This report presents the findings of this Ad hoc Expert Group on Market Competition in the Nuclear Industry. It covers market competition in the supply of goods, materials and services for the design, engineering and construction of new nuclear power plants (NPPs), for the front and back ends of the nuclear fuel cycle, and for the maintenance and upgrading of existing NPPs. These markets are analysed to determine if effective competition exists, and to identify the various constraints which may limit it. To provide context, some aspects of the historical development of these markets are also included. The study also considers the potential implications for market competition of the broad types of multilateral assured fuel supply arrangements which have been proposed by several governments.

In examining market competition in the nuclear industry, the expert group also kept in mind that there are some areas of nuclear activity where competition is necessarily limited or even absent. This includes many research and development activities, especially those with a longer term goal, where international co-operation and government support are necessary until new technologies are ready for commercialisation. Within existing commercial sectors, certain limitations also necessarily exist, notably non-proliferation controls on sensitive materials, equipment and technologies.

Building, operating and maintaining NPPs over their operating lifetimes of up to 60 years involves very large investments in complex plant and equipment, and requires a high level of specialised expertise. This often results in long-term relationships being developed between suppliers and customers, who work together to ensure that plants operate safely and efficiently, and that improvements and upgrades can be made effectively.

This can serve to limit competition, but may also be in the best interests of NPP owners, since the costs of lost production resulting from an unplanned outage could quickly outweigh any cost benefits from changing supplier. In some market sectors, such as maintenance and fuel fabrication, changing supplier may represent a significant risk to NPP owners. Thus, it is important to recognise that competition in the nuclear industry is not simply about price, but that quality and reliability are often at least as important.

Assessing the competitiveness of markets

In order to make objective judgements about the competitiveness of the various markets for nuclear energy related materials, goods and services, it is first necessary to define some criteria against which the market characteristics can be assessed.

In principle, the competitiveness of a given market can be assessed numerically by analysing the details of a large number of transactions. However, this requires a very high degree of market transparency, including knowledge of prices and costs. This can work well for markets where there is a large number of suppliers and consumers, and many transactions for which data are available.

In general, nuclear-related markets are characterised by relatively small numbers of both suppliers and consumers. Individual transactions are often very large, but few in number. Detailed cost and price information are rarely publicly available. Thus, it is unlikely that a numerical assessment of market competitiveness would be possible.

The approach adopted was to draw up a list of market characteristics which can act as indicators as to the degree of competition in a market. Each nuclearrelated market was examined for the extent to which these indicators were influencing the market situation. Although the assessment of each of these indicators involves a degree of subjective judgement, taken together they provide a useful overall impression of the effectiveness of competition in the markets. These indicators are:

Market shares

This can be measured numerically using the Herfindahl-Hirschman Index (HHI), defined as the sum of the squares of the percentage market shares of all market participants. If this value is >1 800, market regulators usually consider this a sign of over-concentrated market power. Several nuclear-related markets have HHI values above this level.

Degree of vertical integration

A high degree of vertical integration in a market can be a sign of market foreclosure, i.e. companies with a strong position in an upstream sector can use this to maintain or increase their share in downstream sectors.

Proportion of long-term contracts

Where a market is mainly conducted through long-term contracts, this can also be a sign of market foreclosure. Suppliers have sufficient market power to tie up their customers for long periods, limiting the opportunities for new market entrants.

Barriers to entry

There can be many different types of barriers to market entry. They may include the existence of patents and other restrictions on the required technology or know-how, the need for large capital investments, etc.

Transaction costs and market segmentation

This relates to the degree of market integration, i.e. do all suppliers have equal access to all potential consumers. Large differences in transaction costs (such as costs for transport and information) between suppliers can lead to market segmentation and reduced competition. Cultural and linguistic factors, as well as convenience of location for delivery and support services, can also play a role in market segmentation.

Product differentiation

In a perfect market, competing suppliers would supply products which were directly equivalent (or substitutable) for each other. In some nuclearrelated markets, such as uranium supply, the products of different suppliers are directly equivalent, or "fungible". In others, such as fuel fabrication, there may be design differences and quality issues; these can affect the degree of competition.

Balance of capacity and demand

The existence of over-capacity in any market is generally a positive indicator for competition, as it increases consumer choice and tends to lower prices (a "buyers' market"). Conversely, a market with insufficient capacity (perhaps as a result of rapidly growing demand) can lead to reduced competition and higher prices (a "seller's market").

Market alliances and supplier co-operation

Market regulators normally have powers to prevent or punish clandestine collusion or cartel-like behaviour between different suppliers, such as pricefixing. However, other forms of publicly-announced co-operation or alliance between suppliers may be permitted where the impact on competition is deemed to be acceptable. Often such alliances will be limited to certain market sectors or geographic regions. In some circumstances the effect on competition can be positive, if it means that the allied companies can compete more effectively in a particular market with well-established incumbents. Nevertheless, there is the potential to limit competition, so the impact of such alliances needs to be monitored.

Public goods aspects

The concept of "public goods" covers protection of the environment and public health, which in the nuclear industry includes areas such as nuclear safety, radiation protection and non-proliferation. Governments seek to protect public goods through legal or administrative measures, often overseen by one or more regulatory agencies. Companies have to comply with regulations covering the construction and operation of industrial facilities, normally through a licensing process. Of course, governments have a clear responsibility to protect public goods in these areas, but if regulations are unnecessarily burdensome or inefficient, or vary widely between different jurisdictions, they can have a negative impact on market competition.

Trade barriers and restrictions

In addition to regulations designed to protect public goods, there may be additional legal or administrative barriers imposed by governmental agencies or by legal processes which (either unintentionally or by design) have the effect of limiting market competition. These include protectionist measures (such as import tariffs) designed to limit foreign competition, as well as restrictions imposed for other political reasons.

Of course, market competition may be limited as a consequence of barriers to entry and regulations which are obviously necessary or unavoidable. This may be particularly true for nuclear industry markets, many of which involve sensitive and hazardous materials and operations. However, while imposing such necessary restrictions, governments may also seek to limit their impact on market competition. For example, harmonisation of regulations between different countries can remove barriers to competition while still achieving the desired goal.

Not all of these indicators are relevant to all markets in the nuclear industry, and some may be difficult or impossible to assess accurately in particular cases. Nevertheless, where a number of these indicators point to market power being over-concentrated, this can be taken as demonstrating that market competition is being constrained. This indicates that there may be economic benefits to be gained by taking steps to increase competition in these markets, for example by removing certain restrictions or seeking to prevent anticompetitive behaviour.

Competition in the design, engineering and construction of nuclear power plants

The long period during which there have been very few new nuclear plant orders worldwide has led to considerable consolidation among NPP vendors, notably in Europe and the United States. This has led to the emergence of just three major global vendors for light water reactors: AREVA NP, GE Energy and Westinghouse. AREVA NP is a French-German company, GE Energy is a subsidiary of General Electric of the United States, while Westinghouse is a mainly US-based company which is now majority-owned by Toshiba of Japan.

This consolidation has to some extent been offset by the emergence of vendors from other regions (e.g. Japan and Russia) onto the international stage, with others having the potential to do so in the future (e.g. Korean and Chinese companies). Atomic Energy of Canada Ltd (AECL) also offers its pressurized heavy water reactors (PHWRs) on the international market.

It should be noted that the process of constructing a nuclear power plant is a complex one which will often involve several major contractors together with numerous sub-contractors. The contracting arrangements vary from plant to plant, from a turnkey approach whereby the vendor manages the entire process, through the appointment of an architect-engineering company to oversee the process, to in-house project management by the utility (see text box). Thus the main NPP vendors will normally be working with different partners for each project, especially in different global regions. In many countries, an important consideration is the extent to which national companies can be involved in the overall construction effort.

A distinction can be made, however, between the "nuclear island", incorporating the reactor itself and other systems and facilities specific to a nuclear power plant, and the "balance of plant". The latter comprises components and structures which are not specific to NPPs, being similar to those used in other types of power plant (including such major components as turbine generators). The analysis in this report will focus on the market for the supply of the nuclear island and the construction and engineering services which support this, which are normally the preserve of the specialist nuclear vendors.

Market shares

It is possible to examine historical market shares of the various NPP vendors. However, many reactors were supplied by vendors which no longer exist as independent companies, having been taken over or merged with other vendors. Major consolidations which have taken place include:

- Combustion Engineering (C-E) (which built several pressurized water reactors (PWRs) in the United States), was taken over by Swedish/Swiss engineering group ABB (constructor of boiling water reactors (BWRs) in Sweden and Finland) in 1990, resulting in the merger of the two companies' nuclear operations.

- The nuclear fuel and services activities of Babcock & Wilcox (B&W), constructor of several PWRs in the United States, were absorbed into Framatome of France (constructor of PWRs in France and other countries) in 1992.
- The nuclear divisions of Westinghouse Electric, the leading constructor of PWRs worldwide, were sold by their parent company to British Nuclear Fuels (BNFL) in 1999.
- ABB also sold its nuclear operations (including those formerly of C-E) to BNFL in 2000; these activities were subsequently integrated into Westinghouse.
- Framatome was merged with the nuclear activities of Siemens of Germany (which built NPPs in Germany and other countries) to form AREVA NP in 2001, owned 66% by AREVA and 34% by Siemens.
- Westinghouse was sold by BNFL in 2006 to Toshiba of Japan (itself a vendor of BWRs in Japan in partnership with GE). Toshiba presently holds 67% of Westinghouse, with Shaw Group of the United States (an architect-engineering company) holding 20%, Kazatomprom of Kazakhstan (a uranium producer) holding 10%, and IHI Heavy Industries of Japan holding 3%.

The net result is that AREVA NP is the successor to the nuclear activities of B&W (in part), Framatome and Siemens, while Toshiba (through its majority ownership of Westinghouse) is successor to ABB, Combustion Engineering and Westinghouse (although Westinghouse continues to operate independently of Toshiba). AREVA is presently constructing one NPP of its European Pressurised Reactor (EPR) design in Finland, and work has begun on a second EPR in France. The company is also constructing two units of an earlier design of PWR in China, in conjunction with local companies. (One heavy water reactor of a Siemens design remains under construction in Argentina, but AREVA does not have a major involvement in this project.)

Different approaches to NPP contracts

There is a spectrum of different approaches to contracting for the supply of a NPP, ranging from complete responsibility being taken by a single supplier to complete control being retained by the utility customer. However, the main approaches are normally classified into three main types of contracting model, each of which has a number of variations. These main classifications are:

Turnkey approach

A turnkey approach to NPP contracting involves a single large contract between the customer and a NPP vendor (or a consortium led by such a vendor), covering the supply of the entire plant. This will include design and licensing work, supply of all equipment and components (including at the first core of fuel and often several reloads), all on-site and off-site fabrication, assembly and construction work, and testing and commissioning of all systems and the entire plant. The vendor or consortium will sub-contract any elements of the project which it is not able to supply itself. Thus, the contractor takes on full responsibility for delivery of a complete and fully working plant to the customer.

There are several variations on this pure turnkey approach, which may still be described as turnkey. For example, the construction of some support facilities (often described as "owner's scope") may be excluded from the main turnkey contract, and customers with in-house nuclear expertise may wish to retain some involvement in design decisions during the construction process. Nevertheless, the overall responsibility for the construction and integration of all important plant systems remains with the main contractor.

Bidding for turnkey contracts normally involves a small number of competing nuclear vendors or vendor-led consortia, giving the customer a limited choice (each of which will normally involve a different reactor technology). The customer may be able to exert some control over the formation of the consortium by allowing separate bidding (either in parallel or sequentially) for different elements of the project, with a view to asking the successful bidders to form a consortium, which would then be awarded the contract.

Split-package approach

In the split-package approach the project is divided into a few major systems, each of which is the subject of a separate contract with a different supplier. At its simplest, this approach divides the plant into two packages: the nuclear island (essen-

(continued)

tially, the reactor containment building and all systems within it); and the conventional or turbine island (the turbine-generator and associated systems and buildings). More complex split-packages can separate the civil construction work on the whole plant from the contracts for the nuclear and turbine systems, and can also separate out other major electrical and mechanical systems into separate contracts. In each case, there may also be an owner's scope part of the project.

Different approaches to NPP contracts

In such an approach it is necessary to allocate overall responsibility for design and licensing, and for integrating the various packages to ensure that all the plant's systems work together correctly. Such overall responsibility could be taken by the plant's owner (where sufficient in-house expertise exists), or this role could be taken by one of the main contractors (usually the main nuclear island contractor).

Bidding for a split-package project can be carried out independently for each package, with the customer then free to choose the best option for each contract. This works best where the owner is retaining overall responsibility for the project. In other cases, bidding can be by rival groups of companies; this is similar to consortia bidding except that each member of the successful group has a separate contract directly with the customer. The lead contractor of the winning group (usually the nuclear system vendor) co-ordinates the overall project.

The customer can also choose a system of sequential bidding, allowing it first to choose a nuclear system vendor as lead contractor before choosing contractors for the remaining packages (in consultation with the lead contractor). Each contractor has a separate contract with the customer, but works under the overall co-ordination of the lead contractor.

Multi-contract approach

This approach gives the customer the maximum influence over the design and construction of the plant, but also the most responsibility for the success of the project. Only a few large nuclear utilities have this expertise in-house, so in most cases where this approach is adopted an external architect-engineering company will first be contracted to manage the overall project.

The architect-engineer (either an in-house team or external contractor) is responsible for the overall design and for licensing, for inviting bids and selecting contractors for each of the plant's systems [including the nuclear steam supply system (NSSS) and the turbine-generator system], for managing the actual construction work, and for plant testing and commissioning. It often directly employs many of the on-site construction, engineering and management staff. While some major contractors, such as the NSSS supplier, will also have a significant on-site presence, many other contractors supply pre-fabricated systems or components with little or no on-site presence.

Of course, there are many variations within this overall approach, in particular as to exactly how many separate contracts are issued. Breaking the project into a larger number of separately supplied components and systems can maximise the choice of supplier for each (thus increasing competition) or can allow increased local content, but is likely to make more onerous the architect-engineer's task of co-ordinating the project.

For the BWR market, GE Energy remains the dominant vendor worldwide. It has in the past licensed its technology to both Toshiba and Hitachi in Japan. However, following Toshiba's acquisition of Westinghouse, GE has announced the formation of a joint venture with Hitachi (known as GE-Hitachi) for the marketing of BWRs worldwide (except Japan), owned 60% by GE and 40% by Hitachi. A separate joint venture, owned 80% by Hitachi and 20% by GE, will operate in Japan only. Presently, GE is constructing two of its advanced BWRs for the Taiwan Power Company. Some co-operation on BWRs between GE and Toshiba is expected to continue under existing agreements, allowing Toshiba to offer advanced BWRs of a similar design to those offered by GE-Hitachi in some markets.

Licensing of NPP designs by the major vendors to companies in the countries where the plants are to be constructed has played a significant role in the NPP construction business for many years. Indeed, AREVA NP's forerunner Framatome was originally a Westinghouse licensee, although it acquired independent control of its technology in the 1980s. In Japan, Westinghouse PWR technology has been licensed by Mitsubishi Heavy Industries (MHI), which presently has one unit under construction. However, as with the link between GE and Toshiba for BWRs, the future of this arrangement may well be affected by Toshiba's takeover of Westinghouse. In 2007, MHI and AREVA NP announced a joint venture, dubbed ATMEA, to develop a new PWR design for certain markets in the 1 000 to 1 150 MWe range. Meanwhile, MHI has taken steps to offer its advanced PWR design (developed jointly with Westinghouse) in the US market.

Another significant long-term licensing and technology transfer deal was concluded between C-E (now part of Westinghouse) and Doosan Heavy Industries (and other Korean companies) for the development of an indigenous nuclear industry in Korea. This process has progressed to the point where Doosan is now the main vendor of NPPs in Korea, although Westinghouse retains a consultancy role and supplies components. Three NPPs are presently being constructed by Doosan and its partners in Korea.

A similar deal was concluded in 2007 between Westinghouse and China for the gradual transfer of technology to Chinese companies, initially though the supply of four NPPs. Although the China National Nuclear Corporation (CNNC) has developed its own PWR technology, this is less advanced than that available on the international market. CNNC has two units under construction in China, with another in Pakistan. To what extent CNNC will continue to develop its indigenous technology in future remains to be seen.

Also in 2007, the AREVA group signed contracts with Chinese organisations for the supply of two EPRs together with all the fuel and services required to operate them (including uranium supply). The scope of the agreement includes establishing an engineering joint venture which will acquire the EPR technology for the Chinese market (ensuring AREVA's participation in follow-on projects), as well as co-operation in the back-end of the fuel cycle which may lead to the construction of a reprocessing-recycling plant in China. A contract of this size and scope is unprecedented in the nuclear industry, and represent a significant success for AREVA's stated strategy of vertical integration across all sectors of the nuclear industry.

AECL has built its PHWR reactors, known as CANDUs, in Canada and several other countries. A new unit has recently been completed in Romania. An advantage of this type of reactor from the perspective of countries seeking selfsufficiency in energy supply is that it does not require enriched uranium fuel (although, of course, heavy water is required). This technology has been replicated for reactors built in India by the Nuclear Power Corporation of India Ltd (NPCIL), based on two CANDUs built in that country by AECL in the 1960s. NPCIL has three plants under construction in India at present.

The Russian nuclear industry, now consolidated under the state-owned holding company Atomenergoprom, has constructed all the NPPs in the former Soviet Union, most of those in Eastern and Central Europe, as well as other countries. All recent models have been of VVER (water-cooled and watermoderated reactor) designs, which are similar in concept to PWRs. Ten reactors are presently listed as under construction in Bulgaria (2 units), India (2), Iran (1), Russia (3) and Ukraine (2), while two units in China entered operation in 2006 and 2007. Under an agreement between the Soviet Union and the former Czechoslovakia, Škoda was the vendor for most VVERs in the Czech Republic and the Slovak Republic.

Taking into account the consolidations which have taken place, an assessment of the existing world fleet of large power reactors (excluding plants which are permanently shut down, but including those under construction), shows that the combined Toshiba/Westinghouse (including the former ABB and C-E nuclear operations) has built 120 of the total of 434 reactors, a share of 27.6% (see Table 1). AREVA NP (including former Framatome and Siemens operations) is not far behind, with 96 NPPs, or 22.1% of the total. Table 1 also shows that the Herfindahl-Hirschman Index (HHI) for these historical market shares is 1 666, which does not indicate an over-concentrated market. However, this historical data does not, of course, necessarily reflect the current status of the NPP market.

Table 1
Nuclear power plant vendors with total number of reactors built worldwide still in operation (including consolidated companies), and percentage shares.

Company	No. of NPPs	Share (%)	HHI
Toshiba/Westinghouse (inc. ABB, C-E)	120	27.6	765
AREVA (inc. Framatome, Siemens)	96	22.1	489
General Electric (GE) Energy	54	12.4	155
Atomenergoprom	52	12.0	144
Atomic Energy of Canada Ltd (AECL)	34	7.8	61
Mitsubishi Heavy Industries (MHI)	19	4.4	19
Nuclear Power Corporation of India Ltd	16	3.7	14
Hitachi	10	2.3	5
Škoda Praha	10	2.3	5
Doosan Heavy Industries	9	2.1	4
Babcock & Wilcox (B&W)	7	1.6	3
China National Nuclear Corp. (CNNC)	7	1.6	3
Total	434	100.0	1 666

Source: Nuclear Energy Institute.

Table 2
Nuclear power plant vendors with number of reactors completed in or after 2000 or under construction, and percentage shares.

Company	No. of NPPs	Share (%)	HHI
Atomenergoprom	14	25.0	625
Nuclear Power Corporation of India Ltd	9	16.1	258
AREVA (inc. Framatome, Siemens)	8	14.3	204
Doosan Heavy Industries	7	12.5	156
China National Nuclear Corp. (CNNC)	6	10.7	115
Atomic Energy of Canada Ltd (AECL)	3	5.4	29
Toshiba/Westinghouse (inc. C-E)	3	5.4	29
General Electric (GE) Energy	2	3.6	13
Škoda Praha	2	3.6	13
Hitachi	1	1.8	3
Mitsubishi Heavy Industries (MHI)	1	1.8	3
Total	56	100.0	1 448

Source: Nuclear Energy Institute.

Assessment of the recent market shares for the supply of NPPs gives a rather different picture, although this may well be misleading given the small number of new plants which are presently under construction, and their geographical concentration in a small number of countries (for example, there are presently no NPPs under construction in North America). An assessment of the 56 reactors worldwide which have entered into operation in 2000 or later, or which are presently under construction, gives the results shown in Table 2. The largest share of the market in recent years has been taken by the Russian nuclear industry, now consolidated under the Atomenergoprom holding company. However, this includes several long-delayed plants in Russia and Ukraine, as well as more recent orders for NPPs in Bulgaria, China, India and Iran.

Several organisations prepare periodic forecasts of future nuclear generating capacity, which provide an indication of the size of the future market for new NPPs. In general, expectations for new NPP construction have been increasing in recent years, as growing concerns about security of supply and climate change have led several countries to re-assess the nuclear option for the future. However, in practice nuclear growth during the period of primary interest for this study, up to 2020, is likely to be confined to countries where at least tentative plans already exist.

Forecasts prepared by the International Atomic Energy Agency (IAEA), the World Nuclear Association (WNA) and the NEA all show that by 2020, on all but the lowest scenarios, nuclear generating capacity will have risen from about 370 GWe in 2007 to somewhere in the range 450 to 500 GWe. Given that most new reactor designs have a power output of between 1.2 and 1.5 GWe, this implies that roughly between 60 and 100 new NPPs could be built by 2020. For them to be in operation by 2020, orders for these NPPs would have to be placed in the next few years, and no later than about 2015. Most of this growth is expected to be in Asia (notably China, India, Japan and Korea), Eastern Europe (including Russia), and the United States.

It is instructive to look in particular at the crucial US market, where tentative plans for over 30 new NPPs had been announced as of early 2008. Of these, for 27 units the reactor design and vendor had already been tentatively chosen and publicly announced. Westinghouse had 12 potential orders for its AP1000 design, GE had seven for its advanced boiling water reactor (ABWR) and economic simplified boiling water reactor (ESBWR) designs, AREVA had six for its EPR design, while Mitsubishi Heavy Industries (MHI) had two for its advanced pressurised water reactor (APWR) (see Table 3). This indicates that Westinghouse may a dominant share of the US market, but also that the other major vendors are likely to gain a significant number of orders. In addition, it appears that MHI may succeed in entering the US market for the first time.

Table 3
Nuclear power plant vendors with number of potential orders announced in the United States as of early 2008, and percentage shares.

Company	No. of NPPs	Share (%)	HHI
Westinghouse	12	44.4	1 975
General Electric (GE)	7	25.9	672
AREVA	6	22.2	494
Mitsubishi Heavy Industries (MHI)	2	7.4	55
Total	27	100.0	3 196

Source: Nuclear Energy Institute.

An important aspect of the present US market is the licensing system, which has undergone significant reforms since existing NPPs were licensed. The current system allows NPP vendors to obtain design certification from the Nuclear Regulatory Commission (NRC) in advance of obtaining a firm order. Obtaining this certification, which is not site-specific, should mean that the subsequent licensing of individual NPP projects does not need to consider again the generic features of the design. As such, obtaining such certification is likely to offer a marketing advantage, and all vendors active in the US market have submitted one or more designs to the NRC. So far, Westinghouse and GE have designs which have received certification, but Westinghouse has submitted changes to its AP-1000 design and GE has yet to obtain approval for its latest design.

Degree of vertical integration

The complex nature of a nuclear power plant means that the owner/operator of the plant normally requires a considerable degree of "after sales" service from the vendor. In most cases, the vendor also supplies fuel fabrication services, as well as engineering and consultancy services. Replacement components and upgraded equipment and systems are often also supplied by the vendor during the plant's lifetime. Thus, all NPP vendors are also fuel fabrication suppliers and provide most of the necessary services and components to maintain the plant through its operating lifetime.

However, the supply of fuel and other services are distinct markets from that of NPP supply (as discussed in Chapters 3 and 4). While many utilities do favour the original NPP vendor for these products and services, many also look to competing suppliers. All the main NPP vendors are able to supply fuel and services to plants built by other vendors, and other competing companies are also active in these markets. Nevertheless, the original plant vendor may enjoy a considerable advantage in supplying fuel and other products and services to NPPs for which it is the original supplier.

As noted above, the recent series of contracts between AREVA and Chinese organisations represents a new level of vertical integration in the supply of NPPs, going well beyond fuel fabrication and engineering servi-ces. Whether this represents a special case which will not be widely replicated or the beginning of a major shift in the market for NPPs remains to be seen. It is likely, however, that other NPP vendors will increasingly try to position themselves to be able to offer similar deals, where customers require such a comprehensive package.

Proportion of long-term contracts

A contract to supply a nuclear power plant is by its nature relatively long term, and it will normally be part of a relationship between supplier and customer which is likely to continue well beyond the construction phase, often including fuel supply, maintenance and upgrading over the life of the plant. Where a utility is ordering a series of NPPs at more-or-less the same time, it may well be advantageous to negotiate an overall agreement with one vendor. Such multiple ordering may allow a more favourable financial arrangement to be negotiated, and should save on construction and licensing costs. Having several identical plants may also allow utilities to save on operating costs by, for example, sharing equipment and expertise between plants. The best example of such serial ordering is the series of deals between Électricité de France and Framatome (now AREVA NP) in the 1970s and 1980s. More recently, in 2006 Chinese companies reached agreement with Westinghouse for the supply of four units on two sites.

However, despite the possible advantages of such long term arrangement, historically in most cases contracts for the supply of NPPs have applied only to one unit, or to two (or occasionally more) units to be built on a single site simultaneously or in series. This may be because there are rather few utilities worldwide which have nuclear programmes large enough to benefit from such serial ordering from one vendor. In many cases, individual NPP orders have been a number of years apart, with significant design changes between successive NPPs (even where built by the same vendor). In the United States, utility mergers and acquisitions have brought NPPs of various designs under common ownership. Thus, some large nuclear utilities have a mix of plants supplied by more than one vendor (although, as noted above, these vendors may have subsequently merged).

Having learnt from past experience of licensing and construction delays, many utilities now considering ordering new NPPs are aware of the potential advantages of serial ordering. In the United States, for example, the present licensing process is likely to favour a small number of pre-licensed designs. Where utilities are ordering more than one unit, even on different sites, it seems likely that they will often enter into an exclusive arrangement with one NPP vendor.

Barriers to entry

The present NPP vendors have the benefit of many years of experience in the design, construction and maintenance of their NPPs, which has allowed them to develop ever more sophisticated designs. The consolidation that has taken place in the industry has concentrated this knowledge and experience in a small number of companies. Designing and constructing NPPs is a process which requires large multi-disciplinary teams working together over many years, building on past achievements and lessons learned. Overall, it takes many years to develop the skills and abilities to build the advanced NPPs which are now being offered in the market.

On the present outlook, therefore, it seems that the technology barriers to new entrants offering NPPs are formidable. The most likely source of new NPP vendors in the foreseeable future is companies which have developed an independent capability as a result of a licensing or technology transfer arrangement with an existing supplier, as has taken place with Japanese and Korean companies. In the longer term, Chinese organisations are also intending to follow this route. These new entrants may be limited by the terms of their licensing agreement, which may restrict them to certain countries or regions, or require them to act jointly with the original licensor of their technology. Eventually, however, they may develop the technology sufficiently to be considered independent NPP vendors.

Looking to the longer term (beyond 2020), when new and innovative reactor designs may become widely available in the market, there is the possibility that this will involve new actors. A range of companies and research centres from several countries is involved in the R&D activities for such advanced reactor designs. Some of these designs are for small and medium sized reactors (usually defined as 800 MWe or below), which may be more suitable for smaller countries or those with less developed electricity grids, for which existing designs (of up to 1 600 MWe per reactor) may be too large. For example, South African industry, with the encouragement of the government, is developing a pebble-bed modular reactor (PBMR). The initial aim is to construct a demonstration plant with an output of 165 MWe to enter operation by about 2013.

Although it is too early to foresee the shape of the market for NPPs in the longer term, it is clear that there is potential for new entrants to develop innovative reactor designs which will compete with the established NPP vendors. Particularly if the market for new NPPs expands strongly over the coming decades, it remains possible that some new entrants will become mainstream competitors, or will at least establish themselves in regional or niche markets.

Transaction costs and market segmentation

A utility ordering a NPP is purchasing the expertise and design capability of the vendor, more than its manufacturing capacity. While vendors will normally manufacture at least some critical components in their own facilities to integrate design and manufacture, in many cases much of the manufacturing is done under sub-contracts. Some sub-contractors may be local to the construction site, others may be from the same country as the vendor, while others may be from third countries. Thus, while it may be somewhat easier and cheaper for a vendor to build a plant in its home country, in most countries no particular vendor is likely to have a significant geographical advantage leading to lower construction costs.

However, in order to have a realistic chance of winning orders for new NPPs, potential vendors must first bear the significant costs of tailoring their designs to local regulatory requirements in each country where they wish to compete, and often of obtaining prior approval or certification for their designs from regulators. For larger markets, where there is potential for multiple orders and for more than one design to be selected, several vendors may be willing to risk such up-front investment with no guarantee of any return. However, for smaller countries where the number of NPP orders will be limited, some vendors may decide that such costs are unacceptable. This will

effectively limit the choice of vendor available to potential customers in such countries. While some efforts to harmonise regulatory requirements for NPP designs between countries are being made, this remains an important factor preventing all NPP vendors competing on an equal basis across all markets.

Product differentiation

NPPs offered by different vendors differ considerably in their characteristics, even when they are of the same basic design type (PWR, BWR, etc.). This means that customer preferences can play a major role in the selection of a vendor. Indeed, the choice is often more a question of selecting a particular technology rather than the vendor per se.

There are many factors which can influence the choice of a particular vendor or technology for a new plant. Of course, cost will play an important role, with most potential customers requesting tenders from several competing suppliers in order to achieve the best prices. However, there are other important factors which may sway a decision.

NPP vendors are traditionally strong in their home countries, so preference for a domestic supplier clearly plays a role in some cases. Other reasons to select a particular technology may include: existing ownership by a utility of a plant supplied by the same vendor; how well the generating capacity of the competing designs matches the requirement for new capacity; the ability to meet regulatory requirements and the relative ease of licensing each design in the country concerned; and the existence of similar plants which are already in operation elsewhere, giving confidence that the design is reliable and wellestablished.

Balance of capacity and demand

Despite the consolidation which has taken place, there appears to be no shortage of competition to supply NPPs. In recent years, any utility announcing that it intended to build a new NPP was likely to have several design options to choose from, from several different vendors. Given the small number of orders in recent years, and the importance to vendors of demonstrating their new designs, it has been a "buyers' market", with vendors showing a considerable degree of flexibility in structuring deals (including technology transfer).

However, with the prospect of a significant number of new orders from utilities in North America and Europe, i.e. developed countries with established nuclear programmes, the market may be changing into a "vendors' market". In response, some vendors may concentrate their resources on these markets, and pay less attention to developing countries without existing nuclear programmes. Thus, for utilities in these countries it may be that supply options become more limited, and they may find the vendors driving a harder bargain. On the other hand, this could provide new opportunities for regional vendors (such as Japanese and Korean companies) to enter new markets.

Furthermore, the availability of competing designs from a variety of vendors may disguise some constraints in the supply chains for new reactors. Significant parts of these supply chains are not under the direct control of the vendors themselves, but are sub-contracted to other industrial operators. In particular, almost all reactor designs require large speciality steel forgings for the manufacture of pressure vessels and steam generators. There are only one or two facilities worldwide which can prepare the forgings needed for some largereactor designs. In practice, this means that for some projects the only supplier at present for certain large forgings is Japan Steel Works Ltd. Although AREVA is expanding its own facilities in France to enable it to produce such forgings, the prospect of a significant number of new orders in the United States and elsewhere is calling into question the adequacy of the capacity for large forgings.

If there is indeed a resurgence of orders for NPPs, there will need to be a substantial increase in the relevant industrial capacities to prepare the necessary structures, systems and components. Some of this expansion will need to be carried out by the plant vendors themselves in their own facilities, but some (such as large steel components and concrete) may require additional capacity to be provided by other construction-related industries. In such areas, the demand for use of such capacities from other major construction projects will impact their availability for nuclear projects (and their costs).

In addition to industrial facilities, there also needs to be an adequate skilled workforce to design and build new NPPs, while continuing to maintain and upgrade existing plants. At the same time, skilled personnel will increasingly be in demand by regulatory authorities and plant owners/operators. In some sectors, the availability of the necessary skilled labour may limit the rate at which capacity can be increased to meet rising demand. The present age distribution of the workforce in NPP engineering is skewed towards older workers approaching retirement, and it will take time for their experience and knowledge to be passed on to new generations.

Market alliances and supplier co-operation

Co-operation between the main NPP vendors and local companies in the country of construction is a normal part of the NPP market, from the initial marketing process through to construction itself, and extending into the aftermarket for fuel and services. In many countries, this is a necessity for both practical reasons and to satisfy the requirements of the purchasing utility or the government concerned. Such alliances can also help vendors overcome cultural and technical barriers in different markets (including differing regulatory requirements). In some cases this is done on a project-by-project basis, in others it is a longer term arrangement which may cover the development of an entire nuclear programme.

In addition to the full mergers and consolidations noted above, there are also some joint venture and co-operation agreements between the various vendors and potential vendors. The acquisition of Westinghouse by Toshiba has led to a re-alignment some of these agreements. As noted above, GE and Hitachi have strengthened their relationship by establishing joint subsidiaries for the Japanese and global markets, while AREVA and MHI have agreed to a more limited form of co-operation. Previously, MHI had been working with Westinghouse, while GE had been co-operating with both Toshiba and Hitachi in the Japanese market.

While Électricité de France is a major customer of AREVA in France, the two companies also co-operate on the marketing and/or construction of NPPs in some markets. EDF offers its architect engineering expertise for construction of AREVA NPPs where customers prefer this contracting model.

Public goods aspects

In all countries, the design and construction of NPPs is subject to detailed licensing and approvals processes, which are required by legislation. These are necessary to ensure that safety standards are met and that public health and safety are protected. However, even if the aim is identical, regulatory processes differ significantly between countries. This may mean that a NPP design which can be licensed in one country cannot be licensed without significant modifications in another.

Despite efforts, both past and ongoing, to reduce these differences, they often remain significant. This can cause difficulties (and additional costs) for vendors if they have to introduce substantial modifications to their designs for different countries. As noted above, for larger countries where there may be a significant number of orders, the cost is likely to be considered worth bearing. However, for smaller countries with a limited and uncertain market for NPPs, the costs of preparing a custom design to meet local licensing requirements (where they differ significantly from other markets) may be considered an unacceptable risk by some vendors. This may limit the choices available to utilities in such countries.

The transfer of sensitive nuclear technology is restricted under nonproliferation controls. The international supply of technology and materials which are considered "dual use" (i.e. which could have non-peaceful applications), which includes reactor technology and nuclear fuel, will generally require a special export licence.

Trade barriers and restrictions

There are no trade barriers which specifically target the supply of nuclear power plants across borders. However, in general the supply of a NPP to a particular country will require there to be an inter-governmental agreement on nuclear co-operation between the supplier country and the recipient country. Although a network of such agreements exists among most countries with existing nuclear programmes, there are exceptions. A notable exception until recently was the United States and Russia; however, an agreement on nuclear co-operation between these countries was signed in May 2008.

For countries embarking on a nuclear programme for the first time, it may be necessary to establish such agreements before a plant can be ordered. The lack of such an agreement, or refusal to enter into one, may have a public good aspect (i.e. it may be due to non-proliferation concerns). However, such agreements may also depend on other political factors which are not connected with the protection of public goods. In practice, therefore, this may limit the available choice of NPP vendor for utilities in some countries. Under the provisions of the Euratom Treaty, all investments in NPPs or nuclear fuel facilities in EU member states have to be notified to and approved by the European Commission. The Commission has to determine that the investment is consistent with established guidelines for energy and environmental policy.

Conclusions and recommendations

Summary and conclusions for each market sector

Design, engineering and construction of NPPs

After a long period of consolidation and retrenchment due to the lack of new orders in most countries since the 1980s, this sector appears poised for a major expansion in the coming decade and beyond. Despite the prolonged market depression since the 1980s, the remaining NPP vendors have continued to develop their designs and are now offering considerably improved products to those available during the last major periods of nuclear expansion.

At least in the major markets, where there is the potential for a series of orders, there is likely to be strong competition between four or five vendors. Despite some market distortions, notably where vendors dominate their home markets, a global market with several independent and competing vendors has emerged which provides a genuine choice of supplier to potential customers. However, differences in the regulatory requirements for NPP designs between countries, which can lead to significant up-front costs for vendors wishing to enter new markets, may effectively limit the choice available to utilities, particularly in smaller markets.

In the longer term, there is the prospect of the emergence of additional important NPP vendors. The most probable of these are those who have benefited from technology transfer deals with the existing vendors, and have gone on to develop the technology further themselves and eventually reach the status of independent vendors able to offer their distinct designs on the global market. Such companies may well emerge in Korea and China. New vendors based on more innovative reactor designs developed independently of the existing vendors may also emerge, but this is less certain and is likely to take longer.

Uranium supply

The uranium market does not appear to be over-concentrated at present, and the analysis in this report indicates that it is likely to become less concentrated in the next few years as production increases in response to rising demand. There are a significant number of new uranium production facilities expected to enter operation, some under the control of existing major producers but many will be new entrants or smaller producers with growing production. Although consolidation is likely to occur as smaller producers either merge with each other or are taken over by larger producers, the trend is expected to be towards reduced market concentration. However, the possibility of a merger of two of the major producers could be a cause for concern if it led to the merged company controlling a very large share of global production.

Trade restrictions on uranium imports into the United States and the European Union have largely been in response to the availability in the market during the 1990s of significant uranium stockpiles of various types in Russia, which helped to depress uranium prices. However, the availability of such material in international markets is likely to be reduced in coming years, not least as Russian domestic demand is expected to increase. Thus the practical impact of these trade restrictions on the market can be expected to be further reduced, even if the measures themselves remain in force.

UF_6 conversion services

There are effectively only three major suppliers of UF6 conversion services to the global market, with a fourth supplier which is mainly limited to providing uranium, conversion and enrichment as a package. From a market competition perspective, this indicates that the market is more concentrated than would be desirable. Indeed, the market has become more concentrated recently with the conversion plant in the United Kingdom coming under the marketing control of Cameco, in addition to that company's own plant in Canada. However, the alternative to this situation was that the UK plant would have been permanently shut-down. This arrangement currently extends to 2016, after which time the future of the UK plant remains uncertain.

The role of conversion plants as the main storage locations and clearing houses of the uranium market may mean that it is more convenient for market participants if there is a relatively limited number of sites. This facilitates trade in uranium as well as in conversion services. Together with the fact that conversion represents only a small fraction (around 5%) of the total cost of nuclear fuel, this means that new conversion facilities on new sites may have difficulty in establishing themselves. Present expansion plans indicate that the existing major suppliers will expand their capacity as required and little change can be expected in the degree of market concentration.

Uranium enrichment services

The enrichment of uranium uses technology which is among the most sensitive in terms of non-proliferation, which means that there are important limitations on its dissemination and use. This technology is possessed by a limited number of countries, and is entrusted by governments to only a small number of commercial operators, which inevitably limits market competition in this sector.

However, the enrichment supply industry is undergoing major changes which will re-shape it over the next ten years and beyond. The remaining older gas diffusion plants in France and the United States will be replaced by new centrifuge plants, while there is also the prospect of laser enrichment technology being commercialised. There will be at least two and possibly as many as four new enrichment plants in the United States by 2015, each operated independently by competing suppliers. The large enrichment capacity in Russia is also expected to play a larger role in the international market. These developments are likely lead to shifts in the market shares of the existing suppliers.

The prospects for the emergence of new suppliers are less certain. Small enrichment plants are in operation in Japan and China, which could potentially expand their capacity as demand for enrichment grows. Other countries, including Australia, Canada and South Africa, have shown interest in investing in enrichment capacity, possibly using equipment purchased from existing technology holders. Enrichment is one of the main issues being discussed in the context of multilateral fuel supply arrangements, where proposals include the establishment of new facilities under international control, or under the joint control of a group of countries.

Fuel fabrication services

Unlike the generic front-end services discussed above, fuel fabrication is essentially a bespoke service to prepare fuel assemblies to the exact requirements of each NPP. The design and reliability of fuel can significantly affect the overall performance of a plant. Indeed, fuel design can be considered an integral part of the design of the NPP itself. It is no accident that the original fuel suppliers for all NPPs are the NPP designers and vendors themselves, who may have a technological advantage over other fabricators for their own designs of NPP.

Hence, some NPP operators may not consider that the commercial risk involved in changing suppliers is justified by the potential savings on fuel costs, and may maintain a long-term relationship with the original plant vendor as fuel fabricator. Nevertheless, significant competition does exist in the fuel fabrication market, particularly in the United States, and switching of suppliers is not uncommon. For NPPs of more common design there may be a choice of up to three potential fabricators, and as a matter of policy some utilities consider switching suppliers every few years. There is considerable innovation in fuel design, which has led to substantial improvements in NPP output and performance. This is mainly driven by competition among fabricators.

However, while in principle each fabricator/vendor is also able to fabricate fuel for plants designed by other vendors, they will only do so where there is sufficient demand to justify the necessary investment. Thus, for operators of less common designs of NPP the number of potential suppliers may be more limited, and in some cases there may in practice be no alternative fabricator to the original plant vendor.

The fuel fabrication market has consolidated over recent years, as the main NPP vendors have consolidated. This has brought the fuel fabrication operations of seve-ral different NPP vendors (which supplied different designs of NPP) under common ownership. It now appears that the market for fuel fabrication is more concentrated than would be desirable. For some market sub-sectors there is effectively no competition.

As new NPPs are ordered over the coming years, they will be of newer designs which require new fuel designs. Initial fuel loads will inevitably be supplied by the original vendors, who will add new capacity when and where necessary. In some cases, where a large nuclear programme is undertaken, additional capacity may be provided by the licensing of fuel designs to new local fabrication plants.

However, for the longer term development of a competitive market for these designs of fuel, it will be necessary for alternative suppliers to emerge in the international market. This is a matter to which purchasers of NPPs will need to give due consideration when making their choice of reactor technology. Experience has shown that one way to ensure a choice of fuel supplier is to choose a NPP design which is being built in larger numbers, as such designs are likely to be better served by alternative fabricators. The emergence of, say, four or five standardised NPP designs worldwide would potentially encourage a competitive fuel fabrication market to develop.

Spent fuel reprocessing services

Commercial reprocessing plants are in operation in three countries (France, the United Kingdom and Russia), with a new plant due to enter operation in Japan in 2008. Much of the capacity of these plants is used to reprocess domestic arisings of spent fuel, but the three existing plants also reprocess spent fuel from other countries under contracts with foreign utilities. Most reprocessing is carried out under long-term contracts which were entered into some years ago. Several utilities which previously reprocessed spent fuel have subsequently changed policy and are now storing the fuel instead.

As the prospect of significant future expansion of nuclear power is again being considered, the potential for reprocessing and recycling spent fuel is attracting renewed interest. Some currently available NPP models (such as AREVA's EPR) are designed to allow greater use of mixed-oxide (MOX) fuel. For the longer term, the development of new reprocessing technologies is being pursued by several countries. However, along with enrichment, reprocessing technology is highly sensitive from a non-proliferation perspective, particularly if it can be used to produce separated plutonium.

An important new initiative to address this is the Global Nuclear Energy Partnership (GNEP), launched by the United States. Among other things, this aims to develop and demonstrate more proliferation-resistant reprocessing technology. Any increase in reprocessing capacity is likely to be restricted to a small number of technology holding countries, or be subject to multilateral control. The more widespread use of reprocessing is also likely to depend strongly on the adoption of new advanced reactor designs (often referred to as Generation IV designs) which will allow full advantage to be taken of the recycled materials. The timescale for the commercialisation of such designs is expected to be around 2030.

Mixed-oxide fuel fabrication services

Utilities which have had a proportion of their spent fuel reprocessed have thus acquired quantities of plutonium, which can be used to fabricate MOX fuel for use in some existing LWRs. There are presently two commercial plants in operation, in the United Kingdom and France. Fabricated fuel has been supplied to several European countries and to Japan. This has so far been a limited market, driven mainly by the desire of the utilities concerned to utilise their plutonium. MOX fuel fabrication is thus tied to the future of commercial reprocessing, and in the longer term to the deployment of advanced reactor types using fuel containing recycled materials.

Radioactive waste management and decommissioning services

In general, utilities remain responsible for the management of radioactive waste arising in their plants. One management strategy for spent fuel is to reprocess and recycle it, as discussed above. In other cases, spent fuel is simply stored at NPP sites in pools or in dry stores or casks. Eventually spent fuel and other types of waste are to be handed over to a national authority or agency responsible for its disposal. For decommissioning a similar situation exists, with decommissioning wastes being stored or sent for disposal in a national facility.

Thus, commercial activity in this sector is generally limited to the provision of services, technology and equipment. Many specialised companies are involved, as well as many of the main nuclear industry companies. In general, there is a high degree of competition and innovation in the sector. There is some overlap with the markets for maintenance and upgrading of NPPs, so some of the same considerations apply. An increase in work on construction of new NPPs may divert resources away from other sectors served by nuclear engineering firms. However, those companies dedicated to techno-logies and equipment for radioactive waste management are unlikely to be affected. Any increase in demand for their services as a result of nuclear expansion will take some years to materialise.

Services for maintenance and upgrading of existing NPPs

With the lack of orders for new NPPs in recent years, the reactor vendors and other nuclear engineering companies which have emerged from the resulting consolidation and contraction have been increasingly reliant on the business of maintaining, back-fitting and upgrading the existing reactor fleets. Such activities are often important in the context of extending NPP operating lifetimes and improving performance and output. With life extensions now planned for a large number of existing NPPs, the demand for major upgrading projects is likely to remain high. There now appears to be a good balance between capacity and demand in this sector with a good degree of competition in most sub-sectors of what is a multi-faceted market.

However, if there is significant increase in the construction of new NPPs in the coming years this situation could change. Construction of new plants will often involve the same companies as are involved in the maintenance and upgrading sector. It could potentially become more difficult to find competing suppliers able to undertake both routine maintenance tasks and larger upgrading projects in a timely fashion. When considering the industrial capacities needed for an expansion of nuclear power, regard must be given to the capabilities needed to maintain and upgrade existing NPPs.

Supplier dominance of market sectors and vertical integration

The major suppliers in each of the main market sectors discussed above, and their approximate market shares, are set out in detail in the relevant sections of this report; Table 17 shows a summary of the major suppliers in each sector, classified according to the level of market share. This indicates that the most concentrated sectors are enrichment and fuel fabrication, with in each case one supplier having over 30% of the market and others in the 20% to 30% range. Reprocessing is also a concentrated market, although this is a smaller and less well-developed market than the other two.

Table 17
Summary of major suppliers in nuclear industry sectors by approximate market share.

Market sector	Share > 30%	30% > Share > 20%	20% > Share > 10%
NPP construction*	—	AREVA Westinghouse	Atomenergoprom General Electric
Uranium supply	—	Cameco	AREVA Atomenergoprom Rio Tinto
UF6 conversion	—	AREVA Atomenergoprom Cameco	ConverDyn
Enrichment	Atomenergoprom	AREVA USEC	Urenco
Fuel fabrication	AREVA	Westinghouse	GNF
Reprocessing	AREVA	JNFL NDA	Atomenergoprom

Source: Nuclear Energy Institute.
* Including consolidated companies, based on all operating NPPs.

However, the table also illustrates that no sector in the front-end of the fuel cycle has a single company with an overwhelming dominance, with each having at least four competing suppliers. The analysis in this report found that the largest actual market shares in any sector were just over 30%, and no indication was found from presently available information that these shares are likely to increase significantly as the sectors expand over the next ten years. Indeed, in some sectors, notably uranium supply, it appears that the market may become less concentrated over the coming years. In the fuel fabrication market, given that fabrication for a new NPP is usually supplied initially by the NPP vendor, future market shares will be shaped to a large extent by the market for new NPPs. It is likely to take time for a competitive market to emerge for fabrication of fuel for new NPP designs.

In the market for the design, engineering and construction of new NPPs, it is difficult to assess the future market shares of the various vendors, as this will depend on their relative success in winning future orders. However, it is clear that in most regions there is significant competition between at least three or four major suppliers, each of which is offering attractive and competitive NPP designs. In this, the NPP market compares favourably with certain other engineering-based industries with complex high-technology products, notably the aerospace industry. Early indications are that each major NPP vendor will win a significant share of new orders over the next decade. In the longer term new suppliers may also emerge, at least in regional markets.

Table 18
Summary of vertical integration across major nuclear industry sectors for selected companies.

Market sector	AREVA	Atomenergoprom	General Electric	Westinghouse
NPP construction & maintenance	Yes	Yes	Yes	Yes
Uranium supply	Yes	Yes	No	No*
UF6 conversion	Yes	Yes	No	No
Enrichment	Yes	Yes	Planned	No
Fuel fabrication	Yes	Yes	Yes	Yes
Reprocessing	Yes	Limited	No	No
MOX fuel	Yes	Limited	No	No

Source: Nuclear Energy Institute.
* Kazatomprom, a uranium supplier, owns 10% of Westinghouse.

Table 17 also illustrates that several companies have a significant share of more than one sector, i.e. there is a degree of vertical integration across several of the market sectors. The main vertically integrated companies and the sectors in which they operate are shown in Table 18. Insofar as such companies supply nuclear equipment, services and materials as a package (for example, the supply of a NPP in conjunction with a long-term contract for uranium supply and fuel cycle services), this may lead to a reduction in competition in some sectors.

In particular, other fuel cycle companies (which are not also NPP vendors) may be at a disadvantage, as might NPP vendors which could not also offer the full range of fuel cycle services.

To date, such comprehensive arrangements are rare, with most customers preferring to contract separately for each service, at least beyond the initial years of a new NPP's operating lifetime. However, in future some customers may prefer the perceived security of receiving a complete package of services from a single large supplier. So far, only AREVA and Atomenergoprom can be considered as fully vertically integrated, but if comprehensive provision is preferred by some customers, it is likely that others will increasingly try to position themselves to meet this requirement.

Implications of proposed multilateral fuel supply arrangements

Assured multilateral fuel supply arrangements involving the establishment of one or more fuel banks (Category 1 in Section 7) would be expected to closely resemble current market conditions, and would not be expected to have a significant impact on international nuclear markets. However, they could potentially serve to protect the market shares of existing suppliers and to discourage new market entrants in some sectors. On the other hand, some existing trade restrictions could be removed, giving suppliers access to additional customers.

Arrangements in involving guarantees provided by supplier countries or the establishment of multilateral fuel cycle centres (Categories 2 and 3) could potentially result in nuclear infrastructure remaining concentrated in a limited number of supplier countries. These arrangements would require user countries to enter long-term partnerships with supplier countries or participate in multilateral centres in order to secure fuel services, and to forego their own fuel cycle programmes. Such ties could reduce the ability of customers to choose from competing suppliers in the market.

Category 2 and 3 arrangements could also lead to more vertical integration in the industry, particularly if orders for new NPPs were coupled to fuel leasing and take-back. However, they could also be structured to encourage the establishment of additional fuel cycle facilities under independent commercial control, which could add to overall supply and increase competition. In addition, as with Category 1 arrangements, some existing trade restrictions could be removed and supplier access to customers increased.

Two additional important points must be kept in mind. Firstly, many of the details of the proposed fuel assurance arrangements have yet to be developed, so it is difficult to assess exactly how they will impact market competition in the nuclear industry. Secondly, future markets could function using a combination of more than one of the arrangements discussed. Market competition concerns could arise over the dominance of one mechanism over the others, and their overall influence on free market mechanisms.

The analysis here and in Section 7 provides a first step in understanding the market implications of multilateral fuel supply arrangements. Further evaluation of the proposals may be warranted when additional details have been developed. The unknowns to be further refined include: mechanisms for contract transfers among suppliers in case of a contract disruption, the IAEA role in managing a fuel bank, the development of contracts that link NPP sales with fuel cycle supply assurances, and the role of third-parties in providing storage of fuel supplies and of spent fuel.

Key findings and recommendations

- Competitive markets for the supply of goods and services for the construction, operation and fuelling of nuclear power plants are an important factor in ensuring the overall competitiveness of nuclear power, thus helping its benefits to be more widely spread. Governments should encourage and support competition in these markets, and actively seek to prevent concentration of market power where it unduly limits competition.
- An important policy aim of some national nuclear programmes is the development of a domestic nuclear capability. This may necessarily involve some protection of infant industries, with national investment focused on a single supplier to avoid duplication. However, care should be taken not to permanently exclude competitive pressures, which should be allowed to strengthen as market and industrial sectors mature.
- While longer term development and demonstration of new nuclear power technologies may require government support and funding, competition is a great spur to innovation and technological development, helping to improve the products and services available. As fledgling technologies mature and reach the stage of commercial deployment, they should be increasingly subject to the competitive pressures which will allow them to achieve their full potential.
- Strong non-proliferation controls on sensitive nuclear materials and technologies are vital for the existence of open and competitive global markets in the nuclear industry. Such controls will necessarily involve some market restrictions and limitations. Nevertheless, non-proliferation controls are consistent with the development of new capacities by competing suppliers to meet the growing requirements of nuclear programmes around the world.
- Other restrictions and tariffs on international trade in goods and services for nuclear power plants can unnecessarily add to the costs of nuclear power. Governments should aim to eliminate or reduce them to the extent possible.

- The best assurance of supply of nuclear fuel and other essential goods and services to NPPs worldwide is the existence of a geographically diverse range of independent suppliers competing on commercial terms in all market sectors. Governments should seek to create the necessary legal and regulatory frameworks in which such a situation can develop. Furthermore, the harmonisation of such frameworks between countries, especially for the approval of new NPP designs, would increase customer choice and enhance competition in nuclear markets.

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Appendix

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