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Some Policy Challenges of a Global Nuclear Renaissance

Warner ten Kate & Jacques de Jong

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Introduction

In December 2008, when discussing the role of nuclear energy in the Dutch electricity mix, a Dutch utility ceo involved in nuclear energy, stated that the single one word the audience should remember of his contribution should be: "indispensable".[1] This statement signals a newfound confidence from the nuclear industry that is globally radiating. This newfound *"esprit de corps"* is not necessarily justified, but it does indicate that a significant change in the global debate on nuclear power is occurring.

It could be argued that the debate on the merits and drawbacks of nuclear power generation has not changed in principle since the nineteen-seventies, but globally speaking two general concerns are increasingly highlighted: the debate on energy security and climate change. The global debate on nuclear energy has virtually been frozen since the Chernobyl meltdown in 1986, raising global antipathy towards nuclear power to such levels that building programs came to a standstill. A notable number of countries eventually took measures to abolish nuclear all together, despite the fact that their nuclear reactors had not reached the end of their economic lifespan, or introduced de facto or de jure moratoria on nuclear new build. On the other hand some countries did continue their nuclear programs, (most notably in Asia) or profited from their existing operating fleet (France) despite the ongoing global antipathy.[2]

However, the new millennium brought events that provided incentives to reconsider the global energy mix. Rising energy prices, rising global electricity demand, energy security concerns and particularly climate change concerns brought nuclear back on many national and international political agenda's. In the EU27 Finland took the lead by building its 5th nuclear power plant while countries such as the UK, Italy and Poland have started processes to replace existing reactors or to re-embark on the nuclear option. Sweden decided to terminate a moratorium introduced in the early 1980's while the Netherlands seems to be ready to consider its second plant. However countries such as Germany and Belgium are still holding fast on their nuclear phase-out policy. Outside Europe, newcomers in the MENA-region are starting to seriously look at the nuclear option[3] as well. This trend has continued to capture headlines across the globe in recent years, usually accompanied with the question whether a *"Nuclear Renaissance"* is finally at hand.

In this paper we will take a closer look on the various motivations to pursue (again) civil nuclear generation capacity and explore some of the challenges and opportunities a nuclear renaissance might provide for the future. As a point of information, table 1 gives an overview of the present status of nuclear power plants in the world.

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[1] CIEP Energy Policy Meeting: *"Nuclear Renaissance in the European Union?"* held at the Clingendael Institute December 4th 2008 in The Hague. http://www.clingendael.nl/ciep/events/20081204/

[2] Also South Africa and Iran could be seen in this category although "other security concerns" are perceived to be or have been relevant as well.

[3] Reference could be made to Turkey, but more interesting to oil-producing countries such as the Emirates and Libya that have increasing problems with fuel for power generation.

A Global Nuclear Renaissance?

The share of nuclear generated electricity in the global energy mix is under considerable scrutiny. The International Energy Agency in its 2008 World Energy Outlook (WEO 2008) projected in its reference scenario that nuclear electricity generation will decrease from 15% in 2006 to about 10% in 2030.[4] However, total nuclear generation capacity will see an annual increase of 0.9% in generation capacity until 2010. More interesting however is the IEA's global conclusion that the trends in this "business-as-usual" scenario are unsustainable, basically from the impacts on climate change. Therefore, two other scenarios are developed, based on the desirable political outcomes of limiting global temperature increases to 2º C or 4º C in 2050. The acceptable levels of CO² in the atmosphere are respectively 450 and 550 ppm, and especially the 450-ppm scenario is worthwhile looking at.

The 450-ppm scenario explores the technology options that would bring total emissions in line with the 2º C climate objective in 2050. As can be seen in figure 1a, which is coming from the IEA's Technology Study, the largest shares will come from energy savings and from renewable energy, but the more conventional sources such as nuclear energy, will still be needed. Figure 1b gives a further indication with a break down of the fuel mix in global electricity generation in 2050, when renewables are covering about half of all fuel inputs, but nuclear energy also playing a substantial role.

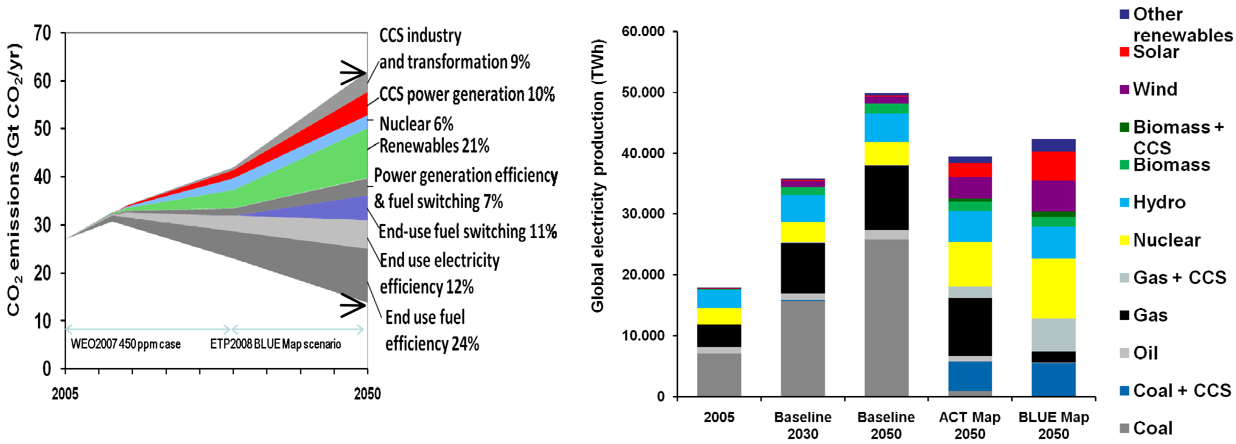

Figure 1a & 1b. Energy Technology contributions in 2050 meeting the 450 ppm objectives and the consequences for the fuel mix in electricity generation. IEA Energy technology perspectives 2008

The major efforts required become even more striking when we look what investments in new power generation facilities would be necessary in the period up to 2030 in order to meet the 2050 climate change objectives. Figure 2 gives a revealing indication on what would be required, for instance requiring annual capacity additions of some 17 GWe in wind energy around 40 large fossil fuel plants with CCS, together with some 30 GWe nuclear plants. The

[4] *'World Energy Outlook 2008'* International Energy Agency (Paris 2008) 507.

industrial efforts to meet these targets in terms of project management, logistics, siting and. licensing would be enormous.

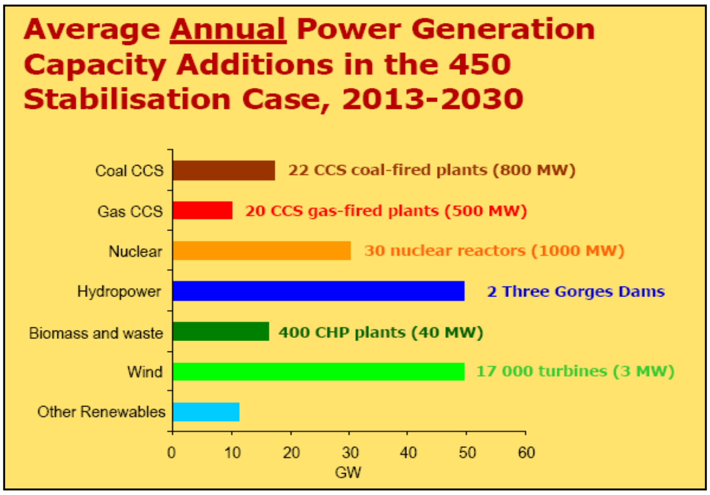

Figure 2 The energy industry challenge of the 450-ppm scenario. IEA World Energy Outlook 2008

Building upon the IEA findings, the OECD Nuclear Energy Agency published in 2008 its first ever Nuclear Energy Outlook. This outlook takes a view up until 2050, developing a high and a low scenario. Both scenarios take favourable views of future nuclear energy development.[5] The high scenario suggests that 1400 reactors (1000MW) could be in place in 2050 creating a near fourfold expansion of 2008 capacity. The low scenario still creates a near doubling of global capacity creating the need for 600 reactors (1000MW) in 2050. However, replacing a large share of the current 436 operating reactors would still require a considerable construction programme worldwide.

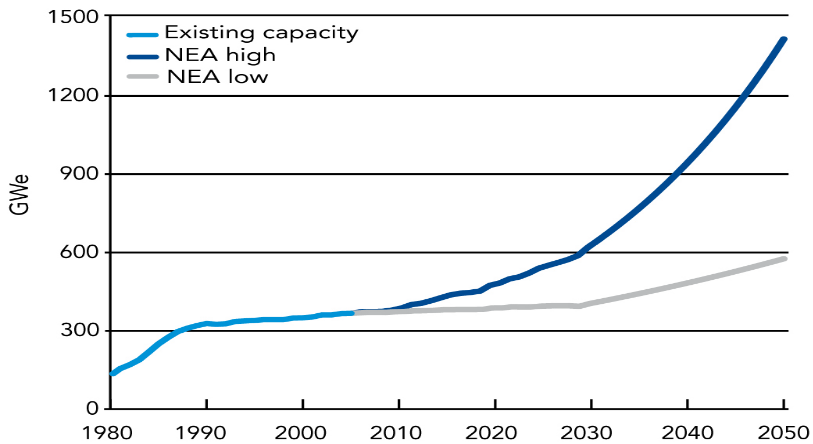

Figure 3: Nuclear Energy Outlook global nuclear capacity [6]

[5] *'Setting the scene: the Global Outlook for Nuclear Power'* Presentation held by Mr. Stan Gordelier, Head of Nuclear division at the Nuclear Energy Agency at the Clingendael Institute on March 10th 2009. http://www.clingendael.nl/ciep/events/20090310/

[6] *'Nuclear Energy Outlook'* Nuclear Energy Agency (Paris 2008) fig. 3.11.

Both the high and low policy case is technologically feasible according to the NEA, but policy and regulatory frameworks are critical, together with still outstanding issue of public acceptance. As to the technology, the nuclear deployment for the 2050 period could be based on currently available generation III(+) reactor designs. Although these designs would bring 100-year life cycles (10 years planning and building, 60 years of operations, 30 years of decommissioning), exclusive of final waste disposals, further technological development is on the research policy tables. New reactor designs in the so called generation IV family are explored, focussing on further fuel efficiency (including the option of breeders) and more sophisticated fuel cycles, including the reduction volumes and lifetimes of highly radioactive waste for final (geologic) disposal. These efforts however are not considered as critical in order to contribute to the short and mid-term goals on expanding the nuclear share in the fuel mix.

Continuous and broad based political support in the medium term for nuclear reactors is however crucial to kick-start a short term consolidation of nuclear power and a possible future renaissance of nuclear in the fuel mix. This would require the creation of a sound and stable market environment, giving the right incentives for investor confidence. It would also need stable government views and policies regarding safety and environmental issues, in addition to clear and effective frameworks for the nuclear fuel cycle. On this point, issues should cover the front end (fuel and fuel service availability and supply security) and the back end (waste management and final waste disposal). Issues should cover also the further strengthening and enhancement of the (international) non-proliferation regime. But, again, more generally all these elements are critical in building trust and confidence in the wider and more difficult areas of public awareness, acceptance and -maybe- even support. These elements are equally relevant for nuclear developments in the EU and in the US,[7] as they are in Asia.

These policy issues will be further discussed in this paper, both in the context of the energy policy perspective as such and in relation to more wider policy and public concerns.

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[7] Warner ten Kate '*US Nuclear Industry Back in the 'Fast Lane'?'* Clingendael Institute, CIEP Briefing Paper 9 (The Hague, 2008).

Energy policy drivers for nuclear energy

Energy policy can broadly be described as trying to achieve the availability of energy at all times in various forms, in sufficient quantities and at reasonable/or affordable prices with the least possible harm to the environment. These objectives constitute the main three pillars of any national energy policy: security of energy supply, market and price efficiency and the environment.[8] It is therefore useful to explore these three pillars from the nuclear power perspective.

Price efficiency: A level playing field?

Usually in market economy a certain price outlook has to guarantee that nuclear energy is an attractive option for electricity generation. Electricity generation characteristics of nuclear energy however require specific considerations in order to make the right assessment in relation to other fuels. Firstly, the investment profile of a nuclear reactor is such that upfront investment in capital costs dominates the way nuclear power will be used in the electricity mix.[9] The fuel costs for nuclear power are only 14% of total capital expenditure over a nuclear plants lifetime.[10] This will not only mean that financial risks are concentrated during the construction period, but also that a nuclear plant has to produce electricity from the day it is operational to recoup on the considerable upfront capital investments.

The investment profile requires therefore base-load generation. But also technical requirements of nuclear power stations do not allow for on- and off-switching during peak hours. Although the nuclear industry claim that Generation III+ reactors and possible Generation IV reactors will have generation characteristics that will come close(r) to more flexibility, the need to recoup on upfront investments make it still likely that base-load operation will remain the rule. It is therefore directly in competition with coal as the other main base load source. Coal is generally considered as the cheapest source of electricity generation (even in a constrained world), due to its low cost technology and cheap and plentiful fuel availability.[11]

Nuclear has basically to compete with coal, being therefore not only less attractive in countries with large coal reserves (such as China), but will also be influenced by the impact of carbon pricing. In a carbon priced environment even high gas priced power generation will remain competitive due to its low capital costs[12]. Although high carbon premiums will play a role in inter-fuel competition, the longer-term economic case for nuclear in a liberalized electricity market setting the choice for nuclear might even be more dependent on capital costs and low gas prices. Low fuel costs relative to large investment upfront, makes nuclear power generation a possible hedge on future electricity prices by providing a price ceiling. However this is not the case in a highly liberalized electricity market where generators find it difficult to pass cost rises on to consumers.

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[8] Femke Hoogeveen and Wilbur Perlot eds. *'Tomorrow's mores: the international system, geopolitical changes and energy'* Clingendael International Energy Programme (The Hague 2005) 22.

[9] Total costs for a nuclear reactor are currently estimated to be around 5 billion Euros'.

[10] Nuclear power generation cost benefit analysis. Source: http://www.berr.gov.uk/files/file39525.pdf

[11] *'The future of coal: options for a carbon constrained world'* Massachusetts Institute of Technology (Cambridge 2007) ix.

[12] Presentation of Dr. William J. Nuttall, *'Nuclear Energy Economics in a world of CO2 permits and volatile energy prices'* Chatham House, November 17, 2008.

Liberalized energy markets are not always giving the right policy or even political incentives for investments in large scale, financially vulnerable and long term construction programs such as nuclear power plants[13]. Especially when the choice for nuclear is considered as appropriate from the perspective of a wider "social" or public optimal fuel mix, then would be the case when the economic argument would prevail. In a price setting market environment, investment in nuclear would be less justified at the higher end of the range of costs, or in a low gas price world due to its investment and electricity generation profile. Specific policy measures to secure long-term investor confidence might then be considered. We will discuss this further in the next section of this paper.

Availability & Security

Nuclear electricity generation is less dependent on fuel price rises since during a sixty-year lifespan it amounts to only a minor share of total generation costs.[14] In addition it is generally acknowledged that the size of available uranium reserves are sizeable enough to enable future nuclear electricity generation.[15] In any case there will be enough uranium present to facilitate electricity generation up until 2030 after which it is expected that technological development (Generation IV) will change the way fuel is used. In addition future technological development could also broaden the fuel base to include thorium and plutonium in a secure way.

Apart from being plentiful, one of the main advantages of uranium as the major fuel source for nuclear electricity generation is that it is considerably geographically dispersed. As shown below in Figure 4, the main reason that uranium is considered secure by major OECD fuel users is that considerable reserves are present in fellow OECD countries most notably Canada, United States and Australia. This allows for a more secure value chain for nuclear energy since it is thought that ownership risks in uranium mining are considerably less in OECD countries as opposed to ownership risks in the oil value chain.

In addition "security" considerations might be very different amongst various uranium importing nations. For example: for the United States a drive for a more secure fuel mix is focussed on reducing the reliance on imported petroleum of which it imports nearly 60%. American appetite for petroleum derives from its transportation sector that is dependent for 96% on petroleum products. However, as the United States electricity mix is not necessary over dependent on imports and does not feel insecure about the imports from Canada and Mexico (Both NAFTA members). A move towards nuclear in the US' highly liberalised electricity market might seem bizarre when one considers that the U.S. has the largest coal reserves in the world. However, as a diversified electricity mix might be considered most secure it would provide for a social desired outcome, especially when one considers that a larger share of the value chain is highly technological for which conditions are present in the US. In the very long run as electrification of transport progresses it might even be feasible that nuclear energy can actually contribute to a reduced dependence on imported petroleum.

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[13] The same holds true for instance for new large-scale energy infrastructures.

[14] Even of the 14% fuel costs in the total costs of a reactor lifespan only 30% is reserved for uranium, the other 70% are for fabrication and waste related costs.

[15] *'Uraniumwinning: voorzieningszekerheid, milieu- en gezondheidseffecten en relevantie voor Nederland'* Clingendael International Energy Programme (The Hague 2006) viii.

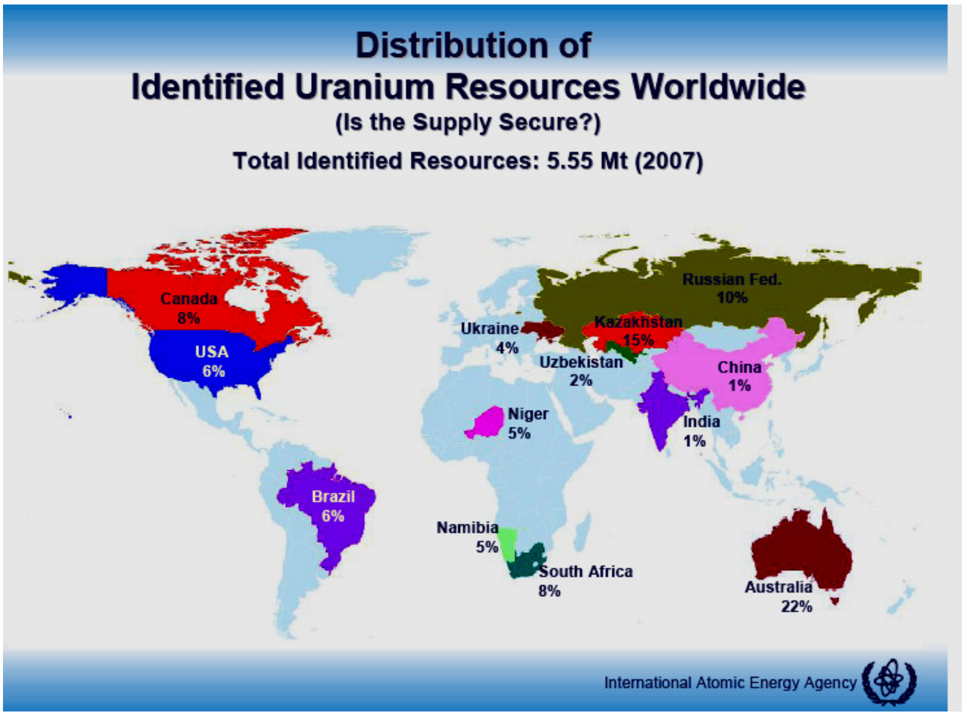

Figure 4: Global distribution of uranium reserves[16]

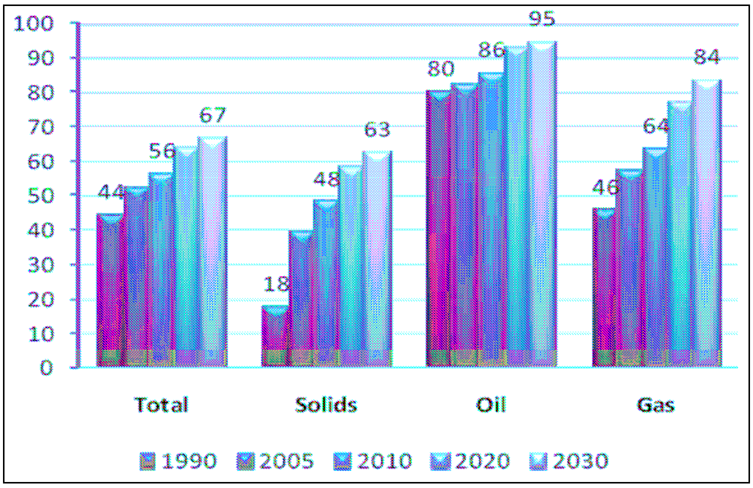

Figure 5: The European Union's import dependency through 2030[17]

As shown in figure 5, the EU is and will be very much more dependent on petroleum imports than the US. However for European nations energy security is very much considered a gas related issue as the 2006 and 2009 supply disruptions of Russian gas import have shot this topic

[16] Presentation Steve Kidd, *'Nuclear Fuel'* Chatham House, November 17, 2008.

[17] Source: European Commission 2008.

to the top of policymaker's agenda's. As coal imports are projected also to rise up until 2030, nuclear might provide for an alternative to manage these flows. Even in a liberalised European energy market provided that a carbon will be priced and gas prices continue to rise. In addition Europe has a considerable technological base and experience for nuclear power, it is therefore technologically self sustainable throughout the whole business cycle, especially including the front and back-ends of the fuel cycle, this rather unique characteristic would be a further asset to secure the value chain of nuclear power[18].

In large energy consuming developing nations (namely China) the security of technology issue is also a consideration. While China has plentiful coal reserves its growing urbanised centre's benefit from nuclear power and can absorb the large amounts of electricity produced by nuclear reactors. It is expected that a major Chinese nuclear construction and operating company will emerge in the future, securing operating experience with western technology now, will benefit and secure future nuclear development in China. Maintaining or expanding nuclear in a national electricity mix as part of a social optimal electricity mix can be furthered by very different national security considerations of which reducing dependence on foreign sources is but one.

Environment, and Safety

Safety of operations is a prerequisite for any attempt to revive and expand the nuclear industry, the direct environmental consequences of a nuclear accident may be (more or less) local/regional, but the effects for the industry will be felt globally. Impeccable operating history is of the utmost importance, as is the information sharing amongst utility companies and countries. Numerous arrangements, both at industrial and at government levels are in place, with a wide array of monitoring, verification and peer-reviews. It should be underlined as well that the IAEA has embarked on a far-reaching set of safety principles, codes and guidelines that are leading in national and even forthcoming EU legislation.

Using therefore state-of-the-art technology and knowledge would for countries considering (again) the nuclear option diminish safety risks. Present state-of-the-art reactor technology such as the generation III family (including the EPR) would meet those requirements. When large-scale nuclear deployment is pursued, using a single reactor technology could create additional risks when design-specific safety failures would occur, with consequences for the whole nuclear fleet. Here again, we see that energy utilities might therefore opt for choosing more than just one reactor design.

In that context, the importance of high qualified and independent regulatory oversight should also be stressed. And here again, international mechanisms for best practices and periodical peer-reviews are available and would help bridging still existing public safety concerns. Public acceptance of nuclear safety however is still a major issue that defies operational and scientific evidence and should not be underestimated.

As the threat of climate change is virtually universally accepted as an issue that must be dealt with, governments around the globe try to formulate policies to reduce carbon emissions. Pivotal in these policies is a price on carbon emissions providing an incentive to reduce these emissions. However as governments try to develop policies that favour carbon free electricity generation, the nuclear industry has lobbied feverously to include their source of energy as renewable, presenting itself thereby as "green".

[18] It should be noted that both enrichment and reprocessing technologies are deployed in the EU at industrial scales. No other region in the world, including the US, Russia or China, has as yet such experience.

Despite the very controversial and hotly contested claim that nuclear electricity would be "green" it is uncontested that lifecycle carbon emissions of nuclear generated electricity are up to par if not better than most renewable sources (Figure 6). Faced with the threat of Climate Change this might create a short-term trade-off in favour of nuclear in which priority between two evils is given on the basis of the more direct threat. However this does not mean that the even longer outlook on environmental hazards of nuclear waste still require an adequate solution. As the NEA considers an effective technical solution to radioactive waste possible by 2050, opponents of nuclear power object to this reliance on "still-to-develop" technical solutions.

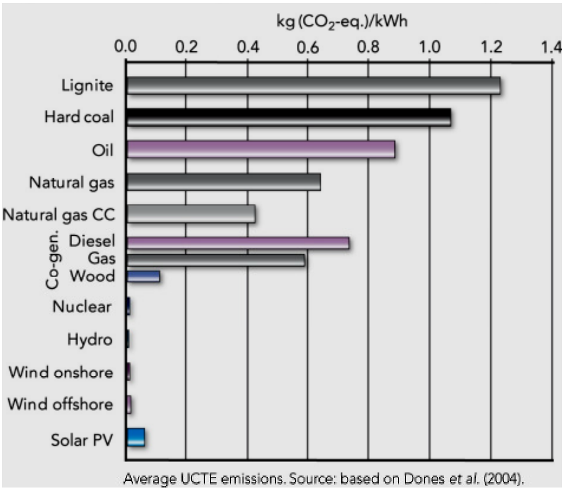

Figure 6: Greenhouse gas emissions of selected energy chains[19]

Currently a debate is developing whether the storage of high-level nuclear waste is comparable to the capture and storage of carbon from fossil fuel fired electricity generation. Proponents of nuclear power would argue that storing CO_2 underground would require it to remain underground forever. High-level radioactive waste at least diminishes over time, albeit taking 300.000 years. The trade-off between relatively short term (2050) climate change concerns and long term waste issues has influenced the debate on electricity generation in favour of nuclear, however the industry and governments are still banking heavily on future technological developments to control the amount of high radioactive waste.

[19] Coming from *'Setting the scene: the Global Outlook for Nuclear Power'* Presentation held by Mr. Stan Gordelier, Head of Nuclear division at the Nuclear Energy Agency at the Clingendael Institute on March 10th 2009. http://www.clingendael.nl/ciep/events/20090310/

Major global public issues regarding a "nuclear renaissance"

Beyond the three issues regarding the energy policy objectives per se, nuclear energy has wider political dimensions as well. These are related to global public awareness and acceptance and play a strong role in policymaking and implementation. We will address these further and discuss to what extent they could be seen as impediments to further nuclear reactor deployment. The first one to be addressed is the business perspective, the market model for new investments. The second one has everything to do with the waste issue, and notably the acceptance of technical solutions for final high-level waste disposal. The third one then is about international geopolitical and security issues, issues dealing with safeguards against non-peaceful use of the technology and its materials and the more global wider dimensions of nuclear non-proliferation. This last point will be discussed more extensive, where we will also take into account the issue of access-to-technology and access-to-services.

We would note explicitly that nuclear safety per se is not considered (anymore) as a barrier to further nuclear deployment. Present reactor designs, especially of the Generation III+ type are generally considered as acceptable from a safety perspective. Safety conditions in the form of the tight standards and regulations that are necessary have been developed to high safety-levels, including the procedures and analytical tools to demonstrate sufficiently that they will be met. Operational aspects of nuclear safety then still have to be met, where inspections, monitoring and above all the practice of a high safety culture and environment are further key to maintaining public confidence success stories.

Addressing however the issues mentioned in a way that will build more public confidence does not necessarily mean stronger and broader public acceptance. Specific policy approaches will have to be developed, including public participation processes in all relevant aspects of decision-making. We will discuss this a further at the end of this section.

The global investment climate

In the EU, the prevailing single market paradigm is putting a strong emphasis on competition and on market forces. Inefficiencies in infrastructures and overcapacities in electricity generation have been sweated out in the last 2-5 years. This process is still ongoing, but supply security concerns in power generation are back on the agenda. Policy makers are discussing to what extent market designs will have to be amended to give the necessary incentives for new investments in electricity generation. Longer-term policy aspects with regard to sustainable development and climate change are a substantial part of these debates. The same is applying to the question to what extent nuclear energy has to play a role in the longer-term energy mix in the EU. And, if so, what market conditions and regulatory models would be needed to support the nuclear option.

Planning and building new nuclear power plants (NPP's) usually require lengthy procedures. Investor confidence is strongly related to assessing these regulatory risks in addition to the economics of operation. Decommissioning and the back end of the fuel cycle are risk factors as well, with a mix of economic and regulatory uncertainties. The competitive market environment and the risk management schemes during planning, building, operation and decommissioning of NPP's should be under great scrutiny to assess barriers for investment and possible solutions to overcome them.

Regulatory risks

As such, when licensing conditions for new NPP's are clearly set, well in advance and further procedures are well defined, there should be no additional risks for investors. Risks will increase when rules and conditions are not stable, or when appeal procedures become undetermined factors. It would be of great benefit when governments would create regulatory frameworks with strong and transparent time paths and procedures, and ex ante requirement frameworks and the necessary safety and environmental licensing conditions. Some of the following ideas might seem useful for further exploration and consideration at EU levels.

Both within the EU and in the US a number of safety features for licensing have been developed, both in terms of generic safety requirements (such as based on the IAEA NUSS program), in terms of design specific requirements and in terms of site specific requirements. These advanced licensing concepts are developed to give transparency and investor confidence, increasing the possibility of making sound business assessments with regard to economic costs and risks. Whether these existing programs are sufficient or could require some further development should be considered at EU level or in a more direct understanding between interested countries such as in the context of the EPR-program. It should also be noted that the EU recently developed its first nuclear safety directive that basically makes the IAEA nuclear safety principles legally binding in the EU.

In addition, governments could consider offering risk insurance schemes for that part of the licensing process that is open ended. Such schemes have been offered in the US and the US-DOE is authorised to enter into contracts to cover financial losses up to USD 500 million for the first two reactors licensed by the US Nuclear Regulatory Commission (NRC) and up to USD 250 million for each of the following four reactors. Events would be covered such as delays associated with the NRC's review of inspections, tests, analyses and acceptance criteria, including delays associated with litigation procedures in court. Comparable arrangements are as yet not on agendas in the national or wider EU context and it could be of interest to analyse if such steps would be needed and if so be politically feasible.

Economic risks

Market and economic risks offer a more complex picture. Markets are uncertain by definition and since market forces have been introduced for the EU's electricity market, focus shifted towards electricity-generating options with short lead times, such as natural gas. Market conditions and economic risks will have to remain, also for the options with longer-term lead times. Large upfront capital investments required are becoming more expensive as then global financial meltdown progresses and protracts. Expected construction costs have spiralled from a relatively modest 5 billion USD per 2 reactors to about 17-18 billion USD, several times the balance sheet of an average US utility company. However, as investments in nuclear power require long-term views and long-term paybacks, some industry observers expect that financial markets have considerable time to stabilize and that this will in time not affect the capital costs of a nuclear reactor. A number of government schemes have been suggested or are already applied, without putting market conformity at risks. The question is asked to what extent these schemes should be further enhanced in the EU context.

Schemes mentioned or applied include the following. The "Finnish model", where large power consumers are participating in the project building a fifth reactor and commit long-term off-take contracts at pre-agreed (and indexed?) prices. A similar model is considered for a next reactor. The "UK model", where existing NPP's profit during a transition period from nuclear fuel surcharges paid by all electricity consumers. A "carbon price model" such as suggested by

Dieter Helm[20] and others[21], offers a long-term framework in support of low carbon energy sources. Such a framework could even go beyond the present EU ETS by offering government secured long-term carbon contracts. The "subsidy model", where governments "take it all", assuring a system with "contracts-for-differences" and political assurances to pay the price for bringing new NPP's to the market in support of pressing energy policy objectives. The "French model", where the government seems to be guaranteeing all costs related to decommissioning and the back end of the fuel cycle, costs that is usually considered to be the main risk factors for investing in new NPP's. In addition, innovative schemes could be considered with different ranges of risk sharing between the construction, operational and decommissioning phases. Participants in the sharing process could be nuclear vendors, nuclear operators and (groups of) final consumers.

Industrial capacities

There currently is a three-year waiting list for reactors at the one forger (Japan Steel Works) that can produce reactor quality steel. However, investments are likely to be made in forging capacity investment (proposed by Hitachi in the U.S.), but significant lead times remain. However it is a commonly held view that if one is prepared to pay, everything is possible. Possible solution to the cost aspect is increased standardisation of designs that are rolled out in great numbers allowing economies of scale for steel forgers and nuclear constructors. The nuclear industry suffers from a 20-year standstill in training and the imminent large-scale retirement of experienced personnel. Turning this around will require substantial investments, and even more difficult: a turnaround in public perception of the nuclear industry.

Final disposal of high level waste

The backend of the nuclear fuel cycle, and especially the final disposal of high-level nuclear waste, is already decades long a major issue in the nuclear debate. Although technical and environmental acceptable solutions are developed and applied for intermediate storage in many countries, the question of final waste disposal has as yet not found a political and societal acceptable answer. Because of the very long lead-times for final disposal options, empirical proof is hard to provide. Technically the issue might be considered as having been solved in principle, but a publicly fully acceptable solution has not been demonstrated yet. The main focus being on geologic disposal options, discussions are concentrating on where and how. The "where-question" is dealing with locations and geologic formations, where we see an increasing interest of enhancing cross-border cooperation in the EU, including exploring the option of international repositories. We will discuss this "where-question" in some more detail.

The "how-question" focuses on whether or not the waste should be retrievable, in addition with questions about various fuel cycle options. Options for the back end of the fuel cycle have been explored and developed for many decades, including technology and economic aspects. As shown in figure 7, there are basically two options, the "once-through" cycle and the more complicated cycles for reprocessing and re-use of the remaining materials. Once through means that after fuel-use in the reactor, the spent fuel will not be re-treated anymore and after a period of interim-storage brought to a final disposal site. This solution is the leading one in Scandinavia and basically in the US as well. As however the spent fuel could be considered as

[20] See "European Energy Policy, securing supplies and meeting the challenge for climate change"; October 2005; www.dieterhelm.co.uk

[21] Reference Karsten Neuhoff

still economically viable for re-using unburned uranium and the actinides (including plutonium) that have been formed, the technology of separating those materials for further use and re-use was developed from the 1960's onwards. The EU-countries became leading in the deployment of this reprocessing option, starting industrial facilities in both the UK and in France. In recent years we have seen renewed interests in re-use technology, especially focussing on P & T cycles (partitioning and transmutation), where long lived plutonium and other actinides are transmuted into much shorter life times, diminishing the scope of long term disposal by orders of magnitude.

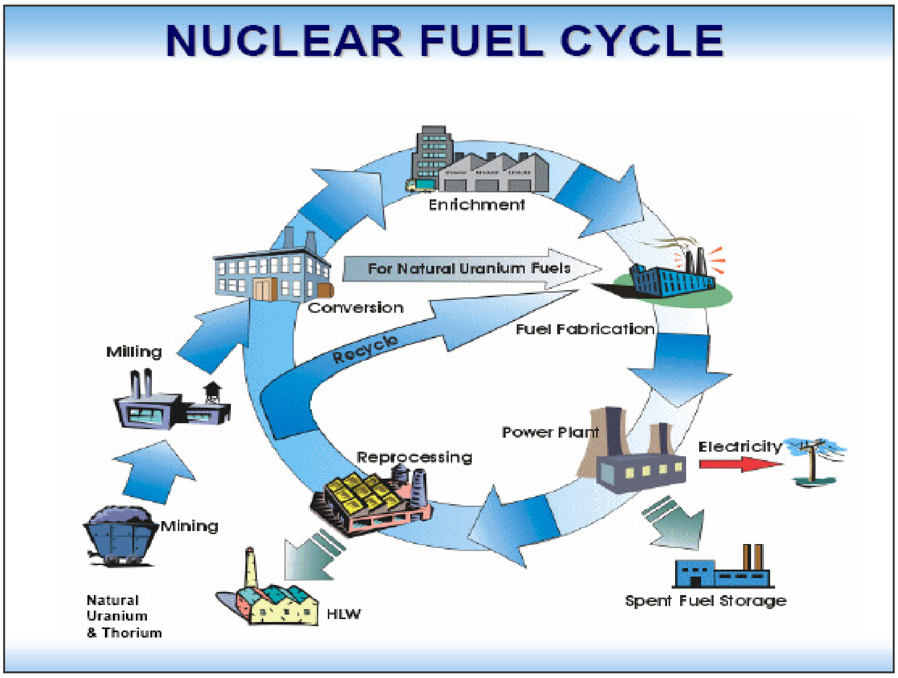

Figure 7 The nuclear fuel cycle[22]

Defining the energy fuel mix and national energy balances is a national responsibility. Within the EU, it increasingly more widely accepted that national fuel mix policies have an impact on neighbouring countries or even for the EU as a whole. This holds true when the nuclear option is applied. Using this option in one country might be beneficial for other non-using countries when they would opt to buy more gas in tightening world gas markets. Countries that are applying the nuclear option or are considering doing so might find it beneficial for them to explore economies of scale and scope for their back-end policies. Most countries have established an institutional framework to handle the back-end on the basis of a national monopoly, although there are various degrees of industrial organisation. These backend organisations are working together and are exchanging all sorts of relevant information, especially when some of the waste treatment is done in other countries and then returned to the originating country. It would make sense to further explore the possibilities of a joint industrial organisational framework. This could be based on the "Joint European Undertaking" model.

[22] Presentation Hans Forsstrom (IAEA), Clingendael 2006; http://www.clingendael.nl/ciep/events/20060124/20060124_Forsstrom.pdf

This model has the advantage of having been developed in the wider EU legal framework and would allow for participation by individual interested national organisations.

An even more appealing approach could be to expand this notion of internationalisation of the back-end, by exploring opportunities for joint installations dealing with treatment, handling and storing of the waste concerned. Many smaller nuclear power programmes are considering whether they will have to make independent provision for disposal. The costs are high relative to the amounts of material involved and national disposal facilities would make poor use of scarce national resources. There are clearly benefits of scale and economy in getting together to develop joint facilities, both for storage and disposal. These facilities might be at a regional level, perhaps serving several neighbouring countries, or truly international, available to users worldwide. A number these countries have already recognised the value of shared facilities and, while pursuing their own national programmes, have started the Arius project to explore the international option in a 'dual track' approach [23].

Arius has embarked on a 2-year project for the development of a road map towards developing European Regional Repositories. This project is now (around 2009) ready to come to the formation of a strategy for the development of shared, regional repositories (via the establishment of a non-profit, European Repository Development Organisation: ERDO). Discussions are starting between the Arius-partners, the European Commission, the IAEA and some eleven interested member states. The objective is to establish ERDO by 2010, as the body that should start to prepare regional repositories for nuclear waste. Figure 8 gives an indication of the project's organisational set-up.

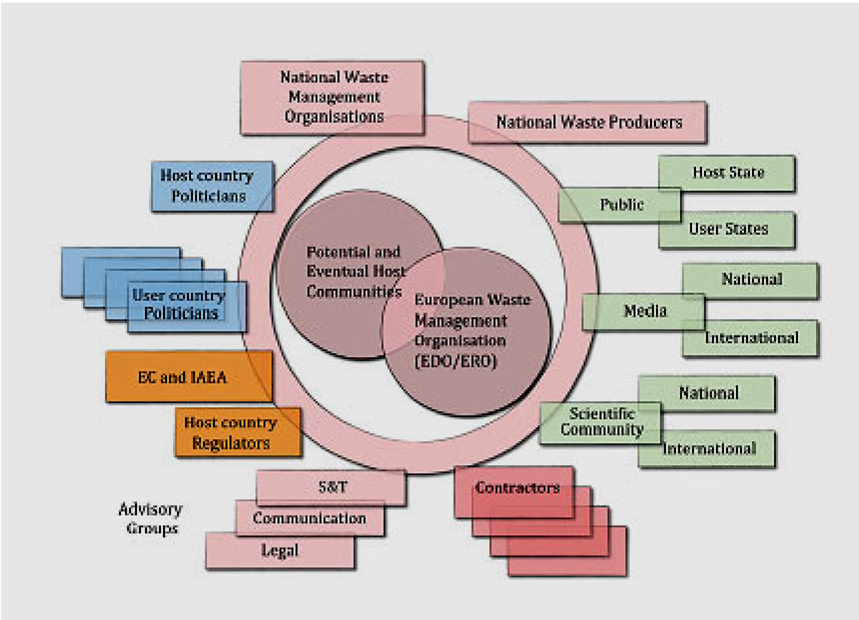

Figure 8 ERDO organisation and stakeholders[24]

[23] This is the so-called Arius –project, where Belgium, Bulgaria, Hungary, Italy, Japan, Switzerland, the Netherlands, Slovenia and Latvia are participating.

[24] ERDO website: http://www.arius-world.org/

Nuclear power and non-proliferation

The greatest challenge to the international nuclear non-proliferation regime is posed by nuclear energy's dual nature for both peaceful and military purposes[25]. Uranium enrichment and spent nuclear fuel (SNF) reprocessing (here after called "sensitive nuclear technologies") are critical from the non-proliferation viewpoint because they may be used to produce weapons-grade nuclear materials: highly enriched uranium and separated plutonium. When the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) was signed in 1968 a compromise was reached between the nuclear-weapon States and the non-nuclear-weapon States to refrain from attempts to develop or acquire nuclear weapons by the latter (Article II) in exchange for "…the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes…" (Article IV), not excluding access to sensitive nuclear technologies.

Non-proliferation concerns have led to a widely developed system of international safeguards, both with respect to technology and installations and fissile materials. The system is legally established in the NPT and is implemented as to its non-military sectors by the IAEA (the International Atomic Energy Agency, a UN agency)[26]. This inspection and verification system works quite effectively on the basis of safeguards agreements that the Agency has concluded with al national governments that have embarked on the use of nuclear However, as time has shown, some countries, under the guise of peaceful nuclear programmes, were involved in clandestine activities aimed at acquiring nuclear weapons capabilities.

In the 1970s the world community started to develop further measures to curb the spread of sensitive nuclear technologies, i.e. enrichment and reprocessing (figure 9). The establishment of a Nuclear Suppliers Group (NSG) in 1975 was one such measure. The NSG united countries that voluntarily agreed to coordinate their legislation regarding export of nuclear materials, equipment and technologies to countries not possessing nuclear weapons. They did not only specify the relevant technology components that are falling under a regime of national export licenses, but were also laying down the notion that the sensitive technologies as such will not be exported or transferred to non-technology holders. This is however only deemed acceptable if access to the technology services for non-technology holders is secured and done on a non-discriminatory basis, provided that the receiving countries has entered into a full scope safeguards agreement with the IAEA. Alongside measures to limit the spread of sensitive nuclear technologies, multilateral approaches to the nuclear fuel cycle (NFC) started to be discussed. These ideas were reflected in the final document of the NPT review conference in 1975 and in a number of IAEA projects on multilateral approaches. However, due to various reasons, including the freezing of nuclear power programmes, these intentions never materialized.

The call for a potential Nuclear Renaissance has made it again increasingly important to link the objective need for an expanded use of nuclear energy with strengthening nuclear non-proliferation by, in particular, preventing the spread of sensitive nuclear technologies and securing access for interested countries to NFC products and services.

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[25] Information in this section is largely taken from the IAEA's website.

[26] It should be noted that the EU via its Euratom Treaty already established a safeguards regime for its member states from the early 1960's onwards, creating a Euratom Inspectorate. Euratom is effectively cooperating with the IAEA through a system of joint inspection teams.

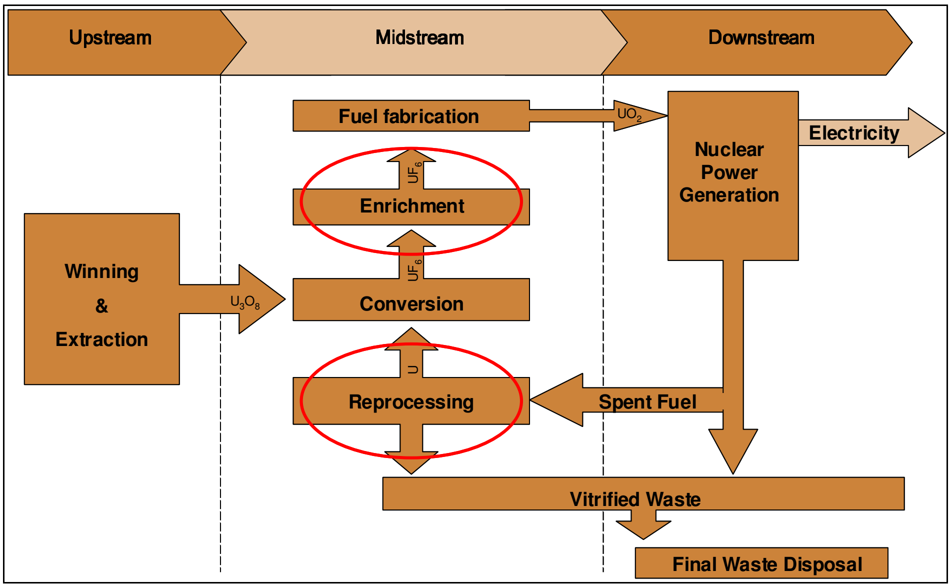

Figure 9: Proliferation sensitive stages in the nuclear fuel cycle

Multilateral initiatives, preferably under the global aegis of the IAEA, should be considered in order to strike this balance. With this in mind, at the IAEA General Conference in 2003, IAEA Director General Mohamed El Baradei called for establishing an international experts group on multilateral nuclear approaches. The proposal was supported, and in February 2005 the international experts issued a report[27] with recommendations on different multilateral approaches. The recommendations contained issues such as the reinforcement of existing market mechanisms; involvement of governments and the IAEA in the assurance of supply, including the establishment of low-enriched uranium (LEU) stocks as reserves; conversion of existing national uranium enrichment and SNF reprocessing enterprises into multilateral ones under international management and control, and setting up new multilateral enterprises on regional and international levels.

Exploring these and other ideas would be worthwhile in particular in the European context. Learning European lessons and exchanging European practices could facilitate wider political perceptions of the role of nuclear energy, including views and ideas on the EU nuclear legal framework. The fact that in the EU sensitive technologies of enrichment and reprocessing are applied at large industrial and commercial scales and that European industry is world leading in these respect ads another dimension. These economic interests will have to be taken fully into account when ideas are further explored. Despite of its political sensitivities and confidentiality, a more open and transparent process of discussion and exploration could also help to demystify these critical steps in the fuel cycle and could help to facilitate "public confidence building" in the wider energy policy and energy security debate, both at European and at more global levels.

In a *general* sense, one could think of the reinforcement of market mechanisms through long term contracts, or the establishment of international supply guarantees (under the IAEA), the promotion of voluntary conversions of existing fuel cycle facilities to multilateral control, or the creation of new (regional) ones with joint ownership. The Euratom experiences with its

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[27] IAEA INFCIRC-640; www.iaea.org

prevailing legal ownership of all fissile materials used for peaceful purposes within the EU and the administrative role of the Euratom Supply Agency as a possible model for wider applications could be useful as well, as would be the existing EU legal instrument of the Joint European Undertaking as a governance model to be used for the enrichment and/or reprocessing parts of the fuel cycle.

In a more *specific* sense, a number of concrete initiatives and suggestions have been developed and are further discussed in the IAEA-framework. The most interesting ones are:

- The suggestions from the World Nuclear Association (WNA) on reinforcing existing market mechanisms[28]. They include additional assurances as a safety net in case of a disruption of market mechanisms or as a collective commitment by suppliers (with IAEA support), to be triggered only if and when a commercial supply contract is disrupted due to political reasons unrelated to non-proliferation. This assurance would require for the recipient State to meet all the non-proliferation conditions.
- The 2006 initiative from Russia to develop a Global Nuclear Power Infrastructure (GNPI) capable of providing secured and non-discriminatory (equal) access to a network of international NFC centres, including enrichment services. The GNPI initiative is aimed primarily at countries that are developing nuclear power but not planning to establish indigenous uranium enrichment and SNF reprocessing capabilities. Russia volunteered to initiate a joint project to establish an International Uranium Enrichment Centre (IUEC) on the basis of its Angarsk enrichment plant. Key principles have been formulated including on non-discriminatory membership, on refraining from the development of domestic NFC capabilities, on transparency of commercial IUEC activities and on cost-effectiveness and investment attractiveness, on the role of the IAEA and on the condition that foreign partners will have no access to uranium enrichment technology.
- The US proposal for a Global Nuclear Energy partnership (GNEP) to contribute to the global development of nuclear energy. In the area of non-proliferation of sensitive nuclear technologies, GNEP aims establishing an international consortium comprised of NFC technology holders that are assumed to become the main suppliers of uranium enrichment and SNF reprocessing services, including options for a nuclear fuel leasing scheme with developing countries incorporating SNF return in order to discourage them from acquiring indigenous NFC capabilities.
- The proposals by the (private) US Nuclear Threat Initiative (NTI) as well as by Russia to establish a LEU fuel bank (or reserve) under IAEA auspices. The NTI initiative was financially kicked off in 2006 by the NTI with a US $50 million donation, contingent on securing an additional US $100 million in matching funds by september 2009. Other pledges came from Norway ($5 million), the USA ($50 million), the United Arab Emirates ($10 million) and the European Union (€25 million) and Kuwait ($ 10 million), meeting the NTI-conditions. It is now up to the IAEA to oproceed with this proposal.

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[28] The May 2006 WNA-report "Ensuring Security of Supply in the International Nuclear Fuel Cycle"; www.world-nuclear.org/security.pdf

- A set of different and complementary proposals by the Urenco-countries collectively and by the Uk and germany individually on assuring enruichment services, including one on creating a commercial enrichment centre with an extra-territorial status.

All these proposals are now subject to further study and discussion within the IAEA. The focus is clearly on enrichment servioces and technology, with the "Iranian issue" in many people's minds. It has already become clear that in the present market environment of over-capacity in enrichment services and a market where military HEU-reserves are reprocessed to LEU for the civil sector, are not making the issue an urgnet one (maybe except for the Iranian case).

Nevertehless, prudent progress is being made, with understandings[29] that any such mechanism should be non-political, non-discriminatory and available to all States in compliance with their safeguards obligations and that any release of material should be determined by non-political criteria established in advance and applied objectively and consistently; and that no State should be required to give up its rights under the *Non-Proliferation Treaty* regarding any parts of the nuclear fuel cycle. The next step would be to agree that all new enrichment and reprocessing activities should be placed exclusively under multilateral control, to be followed by agreement to convert all existing facilities from national to multilateral control. As all proposals have been coming from major players of the nuclear fuel cycle, there is a priority need to hear the positions of old and new customer countries, with commercial aspects and commercial incentives to be looked at as well. One part of a possible new framework is also to reach agreement that all new enrichment and reprocessing activities should be placed exclusively under multilateral control, to be followed by agreement to convert all existing facilities from national to multilateral control as well.

It would also be useful to reflect on these "supply-security" approaches in the wider context of the nuclear non-proliferation policy context as such, especially with a view on the upcoming NPT Review Conference in 2010. Some interesting thoughts on this have been developed by Ruud Lubbers, the former Dutch prime minister[30]. Lubbers is arguing for a "package of eight", including concrete ideas such as the withdrawal of all nuclear weapons in the EU, making real progress diminishing nuclear threats (such as president Obama's first step vis-à-vis Russia on a new START, building on regional successes for nuclear weapon free zones[31] to expand it to other areas), to create a sort of *"Security Council+ for nuclear issues"* (the P5 plus Brazil, South-Africa, Japan, India and the EU/Euratom) taking the lead in realizing a reinforced global nuclear order, with some specific focus on regional dimensions, and to develop a new "nuclear dimension" for NATO.

One interesting element of Lubbers' ideas deserves some additional attention, i.e. the role of EU/Euratom. Euratom should be a key partner in this process for several reasons. The EU represents important non-nuclear weapons states, bringing to the table also its safeguards-inspection experiences. In addition, Euratom has the legal ownership of all civil fissile materials within the EU. This could be seen as an important notion of discussing IAEA governance of any multilateral system on managing or overseeing supplies of enriched uranium, or its (multilateral) technology set-up. Upgrading the IAEA to a supranational authority with legal ownership of fissile materials on the basis of the Euratom model could be

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[29] Understandings such as concluded at the IAEA march 2009 conference on Multilateral Approaches. (http://www.iaea.org/Publications/Documents/Infcircs/2009/infcirc758.pdf)

[30] Reference is made to the "Moving beyond the stalemate" series, as published by CIEP: http://www.clingendael.nl/publications/2009/20090400_ciep_briefing_lubbers.pdf

[31] From Latin America and Central Asia's CANWFZ-treaty to move to Africa and from there to the Middle East.

useful idea in the more global set of discussion between the "10" as indicated. Euratom could also bring its experiences in assessing various fuel cycle options and its industrial and economic with its non-proliferation and security pro's and cons.

Public Confidence building?

Having discussed these three key-issues in building public awareness or even public acceptance in support of a Nuclear Renaissance, the question remains whether it would help. This question is relevant as any further development of nuclear energy at a global scale stands or falls with public acceptance. Without going into further analysis of recent research into the development of public acceptance, it is beyond doubt that in a number of OECD-countries and emerging economies a reconsideration of the role of nuclear energy is developing. A recent global survey[32] indicated that about two/thirds of people around the world believe their countries should start using or increase their use of nuclear power. Most positive reactions were found in India, China, the US and South Africa. About 40% indicated however that this would be conditional on the ability of governments to allay their concerns. Of those concerns, the number one issue is still about efficient high-level waste disposal, followed by safe operations and plant decommissioning.

Public confidence building for nuclear energy deployment is developing as a specific policy, for governments and the nuclear sector alike. Generic approaches have to be combined with very specific case-by-case projects, where the generic one is more about the global policy dimensions and the latter one about concrete projects. In any case, some basic rules are used and mentioned in literature and research projects[33], such as the important roles of transparency, communication & dialogue, accepted & stepwise decision-making processes, and trust in the implementing organisations and national regulators.

More generally however, we should note, quoting work from Malcolm Grimston[34], that the history of nuclear policy-making has been loaded by misperceptions and misunderstandings between the science and political communities. The challenge for politicians and the 'consumers' of their decisions, the voters, is firstly, about reintegrating science into decision-making without making the mistakes of the past, and secondly, about taking strong and possibly unpopular decisions before the impending crises of energy shortages and climate change become unmanageable. Unless these challenges are overcome, complex technologies like nuclear energy, even if they have a useful potential role to play, are likely to be excluded on grounds which (from an objective point of view) will be regarded as irrational.

Certainly, political risks associated with firm action over controversial issues do exist, especially when society does not acknowledge the need for such action. But there are also political risks in ducking difficult questions. Politics is not merely a matter of getting through the next election, as some decisions are inevitably longer-term, casting long shadows. It is something like balancing between the "technocrat" and the "democrat", apparent in the hearts and minds of many policy-makers.

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[32] Survey done by Accenture, January 2009, http://www.engineeringnews.co.za/article/global-survey-finds-growing-support-for-nuclear-power-2009-03-18

[33] Reference is made to the Euratom studies and research projects on Governance, Decision-making and Public Acceptance; see for instance http://ec.europa.eu/energy/nuclear/forum/transparency/transparency_en.htm

[34] The importance of politics to nuclear new build, Chatham House 2005; http://www.chathamhouse.org.uk/files/3290_dec05nuclear.pdf

Concluding remarks

At a global level a "Nuclear Renaissance" is likely to emerge, in OECD-countries as well as in countries such as China, India and South Africa. Wider concerns with respect to energy security and combating climate change are major drivers. In addition, nuclear power would also be a scoring option in the context of the more traditional energy policy objectives such as balancing the competitiveness and environmental policy needs with the objective of energy supply security.

Meeting public concerns however is essential in bringing the nuclear technology option to further fruition. Confidence building measures needed to meet those and other concerns, including those from the business community, will have to be strengthened. They could include approaches and measures that will regard market models and investor assurances (regional) approaches towards final high-level waste disposal options and the more widely political question of nuclear technology and nuclear non-proliferation. On all these measures we provided some further thoughts on how to achieve them.

But finally, we conclude that it all boils down to broad societal acceptance. Developing policies is one thing. To get political and parliamentary backing and approval is the next thing. The main challenge is with implementation. These challenges have to be faced in a "tripartite" level playing field. A field where governments, business and industry are meeting ngo's and other (in) formal representatives of the civil society. Public information, public participation, public awareness and understanding; crucial elements for getting, gaining and deserving the necessary degrees of public acceptance. Organizing these in a timeframe where "time" as such is the real scarcity..........

May 2009	REACTORS OPERABLE		REACTORS BUILDING		REACTORS PLANNED		REACTORS PROPOSED	
	No.	MWe	No.	MWe	No.	MWe	No.	MWe
Argentina	2	935	1	692	1	740	1	740
Armenia	1	376	0	0	0	0	1	1000
Bangladesh	0	0	0	0	0	0	2	2000
Belarus	0	0	0	0	2	2000	2	2000
Belgium	7	5728	0	0	0	0	0	0
Brazil	2	1901	0	0	1	1245	4	4000
Bulgaria	2	1906	0	0	2	1900	0	0
Canada	18	12652	2	1500	3	3300	6	6600
China	11	8587	12	12100	33	35320	80	94000
China: Taiwan	6	4916	2	2600	0	0	0	0
Czech Republic	6	3472	0	0	0	0	2	3400
Egypt	0	0	0	0	1	1000	1	1000
Finland	4	2696	1	1600	0	0	1	1000
France	59	63473	1	1630	1	1630	1	1630
Germany	17	20339	0	0	0	0	0	0
Hungary	4	1826	0	0	0	0	2	2000
India	17	3779	6	2976	10	9760	15	11200
Indonesia	0	0	0	0	2	2000	4	4000
Iran	0	0	1	915	2	1900	1	300
Israel	0	0	0	0	0	0	1	1200
Italy	0	0	0	0	0	0	10	17000
Japan	53	46236	2	2285	13	17915	1	1300
Kazakhstan	0	0	0	0	2	600	2	600
Korea DPR (North)	0	0	0	0	1	950	0	0
Korea RO (South)	20	17716	5	5350	7	9450	0	0
Lithuania	1	1185	0	0	0	0	2	3400
Mexico	2	1310	0	0	0	0	2	2000
Netherlands	1	485	0	0	0	0	0	0
Pakistan	2	400	1	300	2	600	2	2000
Poland	0	0	0	0	0	0	5	10000
Romania	2	1310	0	0	2	1310	1	655
Russia	31	21743	8	5980	8	9360	28	25880
Slovakia	4	1688	2	840	0	0	1	1200
Slovenia	1	696	0	0	0	0	1	1000
South Africa	2	1842	0	0	3	3565	24	4000
Spain	8	7448	0	0	0	0	0	0
Sweden	10	9016	0	0	0	0	0	0
Switzerland	5	3237	0	0	0	0	3	4000
Thailand	0	0	0	0	2	2000	4	4000
Turkey	0	0	0	0	2	2400	1	1200
Ukraine	15	13168	0	0	2	1900	20	27000
UAE	0	0	0	0	3	4500	11	15500
United Kingdom	19	11035	0	0	0	0	6	9600
USA	104	101119	1	1180	11	13800	20	26000
Vietnam	0	0	0	0	2	2000	8	8000
WORLD	**436**	**372220**	**45**	**39948**	**118**	**131145**	**276**	**300405**

Appendix 1 The status of Nuclear power plant deployment; Source IAEA