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Nuclear power and post-2012 energy and climate change policies

Daniel Weisser*, Mark Howells, Hans-Holger Rogner

Planning and Economic Studies Section, International Atomic Energy Agency, Wagramer Strasse 5, 1400 Vienna, Austria

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ABSTRACT

At present there is no binding agreement (at a global level) to address the risk of anthropogenic climate change after 2012. Disagreements abound with respect to a post-2012 climate change agreement, on issues such as economic development, policy criteria, environmental effectiveness, cost-effectiveness, equity, dynamic flexibility, complementarity, enforceability and so on. One such disagreement is whether or not nuclear power should play a role in a post-2012 climate change agreement. This qualitative analysis explores the conditions under which nuclear power could contribute to addressing climate change in post-2012 architectures. It reveals that – given the right framework conditions – some architectures, like ‘cap and trade’ regimes or ‘policies and measures’ can improve the competitiveness of nuclear power plants, while others are unlikely to provide incentives for nuclear energy development in the short to medium term, such as adaptation and technology cooperation. Overall, the study concludes that post-2012 climate change policy should aim at providing policy flexibility without compromising technology flexibility. For example, the provision of long-term commitment periods has the potential to enable better investments in existing low-carbon technologies but stifle the policy flexibility that political decision makers are often keen to retain so that they can respond more quickly to new scientific evidence or advances in clean technology development.

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1. Introduction

The international response to climate change began with the adoption of the *United Nations Framework Convention on Climate Change* (UNFCCC) in 1992 following the *United Nations Conference on Environment and Development* (UNCED) or “Earth Summit” in Rio de Janeiro. The UNFCCC’s principal framework for action aims to stabilize atmospheric concentrations of greenhouse gases (GHGs) to avoid “dangerous anthropogenic interference” with the climate system. The international endeavour culminated with the entering into force of the *Kyoto Protocol* (KP) to the UNFCCC in February 2005, which commits developed countries and economies in transition (known as Annex B countries) to reduce their overall emissions of six

GHGs by an average of 5.2% below 1990 levels between the years 2008–2012 (i.e. the first-commitment period).

There is presently no binding agreement (at a global level) to address the risk of anthropogenic climate change after 2012 (i.e. the expiration date of the 1st commitment period of the KP). Yet, GHG emission mitigation is needed soon and fast. The latest authoritative fourth assessment report (AR4) by the Intergovernmental Panel on Climate Change (IPCC) confirms anthropogenic interference with the climate system (IPCC, 2007a) and the associated risks of climate change impacts to society and the natural environment (IPCC, 2007b).

Two strands of negotiation at the United Nations (UN) level are underway to prepare for a new international agreement to commence after the termination of the KP. These are the

* Corresponding author.

UNFCCC Dialogue on long-term cooperative action to address climate change by enhancing implementation of the Convention,¹ and the Ad Hoc Working Group (AWG) on Further Commitments for Annex I Parties under the Kyoto Protocol.² However, disagreements abound with respect to an international post-2012 climate change agreement, on issues such as economic development, policy criteria, environmental effectiveness, cost-effectiveness, equity, dynamic flexibility, complementarity, enforceability and so on.

One such disagreement is whether or not nuclear power should play a role in a post-2012 climate change agreement. Albeit the fact that nuclear power virtually emits no GHG at the level of the power plant and ranks amongst the lowest electricity generating option with regard to life-cycle GHG releases (Weisser, 2007). Indeed, recent international studies point to a role of nuclear power in combating climate change alongside other energy supply and demand side mitigation options (EC, 2006; IEA, 2006; EPRI, 2007; IPCC, 2007c).

This qualitative analysis explores the conditions under which nuclear power could contribute to addressing climate change in post-2012 architectures. Several key points have been identified that need exploring in order to guide this assessment. The sequence at which these points are listed below also constitutes the outline of this manuscript:

- First, key factors affecting nuclear energy investments in the electricity sector are investigated. This helps to identify which barriers to nuclear power expansion are exogenous to climate change policies – and need ‘treatment’ on a different level – and which ones can be remedied through targeted climate change policies.
- Second, nuclear energy has been excluded from the KP’s Clean Development Mechanism (CDM) and Joint Implementation (JI) as an eligible technology. Clearly an important step for nuclear power to become part of the solution to address climate change is an exclusion of technology-bias from international climate policy agreements. However, in order to remove technology-bias in future international climate policy agreements it is necessary to understand the underlying reasons that have led to the exclusion of nuclear power from the KP in the first place.
- Third, plausible post-2012 climate change architectures are analysed to assess the extent to which they have the

potential to facilitate nuclear power deployment. In order to provide guidance on the question of what constitutes a plausible climate-architecture for the post-2012 period several recent reports have been reviewed.³ In this article, no proposals are made for changes in proposed architectures. Rather it serves to review how nuclear power may fare in each as they stand now.

On the basis of the three analytical parts of this manuscript the key features of probable post-2012 regimes that will be necessary in order for nuclear energy technology to feature more prominently in greenhouse gas mitigation are presented.

2. Barriers to nuclear power development

From a climate protection point-of-view, nuclear power offers significant advantages over other electricity generating technologies, since it has among the lowest life-cycle GHG emissions, while at the same time providing firm and reliable baseload electricity output. However, although the total electricity generation of nuclear power has been constantly rising (partly because of improvements in output and availability of existing plants, and partly because of new capacity) its total global share is not increasing because it is growing at a lower rate than global electricity production.

The key factors that need improving (solving) for nuclear power to increase its share in the supply of global energy have been identified (Rogner and Langlois, 2000; MIT, 2003; Johansson and Goldemberg, 2004) as being (not in order of priority):

1. High-capital cost (and cost overruns).
2. Lead times (and construction-time overruns).
3. Regulatory environment.
4. Safety.
5. Management and disposal of spent fuels and other radioactive waste.
6. Proliferation resistance.
7. Public perception.
8. Poor history of nuclear plant availability during early years of operation.

While each of these points could be deliberated at length (for this please refer to the references), the focus is instead on the ability of climate policy to affect each of these factors. Or, put

¹ A dialogue to exchange experiences and analyse strategic approaches for long-term cooperative action on climate change through an “open and non-binding exchange of views, information and ideas”, with the aim to (i) enable parties to develop national and international responses to climate change, (ii) serve as a forum to identify research, development & demonstration (RD&D) and investment in cleaner technologies and infrastructure, (iii) support developing countries (DCs) to access cleaner and climate-friendly technologies and technologies for adaptation, and (iv) identify approaches which support voluntary actions by DC to mitigate and adapt to climate change.

² The AWG was established to ensure that there is no gap between the 1st and the 2nd (post-2012) commitment period in accordance with Protocol Article 3.9 (future commitments). Work on further commitments (guided by the ultimate objective of the UNFCCC) is set out under three headings: (i) analysis of mitigation potential and reduction objectives, (ii) analysis of means to achieve mitigation objectives, and (iii) the consideration of further commitments.

³ Together over 50 architectures have been discussed in this literature (as summarized by, for example, Höhne and Lahme, 2005; Philibert, 2005; Cosbey et al., 2005; Blok et al., 2005; Wrang and Busk, 2005; Omstead and Stavins, 2005), although not all will be replicated here. This is for mainly two reasons. First, only those architectures are being discussed that have received significant attention in most of the reviewed literature. Second, key negotiation conflicts and deadlocks with regard to post-2012 paths amongst parties to the UNFCCC exist, which in part are rooted in different views on climate science and policy approach. The nature of these differences is such that some climate architectures are unlikely to emerge as feasible alternatives to a post-2012 climate agreement (for a detailed discussion on these differences please refer to Sugiyama et al., 2004; Pew Center, 2005; Bang et al., 2005; Wrang and Busk, 2005).

Table 1 – Technology-risk matrix

Technology	Unit size	Lead time	Capital cost	O&M cost	Fuel prices	CO ₂	Regulatory risk
CCGT	Medium	Short	Low	Low	High	Medium	Low
Coal	Large	Long	High	Medium	Medium	High	High
Nuclear	Very large	Long	High	Medium	Low	Very low	High
Hydro	Large	Long	Very high	Very low	Nil	Very low	High
Wind	Small	Short	High	Very low	Nil	Very low	Medium
Recip. engines	Small	Very short	Low	Low	High	Medium	Medium
Fuel Cells	Small	Very short	Very high	Medium	High	Medium	Low
PV	Very small	Very short	Very high	Very low	Nil	Low	Low

Source: IEA (2005).

another way, given these limitations how would (global) climate change policies affect investment in new electricity capacity?

Most international climate change strategies (apart from perhaps adaptation measures and policies) are likely to affect the cost of providing energy services in states that have agreed to mitigation. Limitations on GHG emissions are bound to increase costs of fossil fuel generated electricity relative to nuclear and renewably generated electricity. Of course, the extent to which cost, prices and investment decisions in the electricity sector are affected will depend on the intricacies of this new international regime, as well as domestic conditions.⁴

The policies and conditions taken domestically and internationally to address climate change largely determine the business and financial risk of financing a new power plant, and thus the choice of technology. Blyth (2005) identifies economic risk, political risk, legal risk and *force majeure* risk to be important considerations for investors under uncertain climate change policies. With regard to the electricity sector *price and fuel risk*, which fall into the category of economic risk, and *regulatory risk* (a political risk type) are considered key variables in making investment decisions (IEA, 2005). So ideally in order for climate change policies to have a detectable influence on changing investment behaviour towards cleaner production technologies, they need to address associated economic and regulatory risks so that the relative economic attractiveness of low-carbon technologies is improved.

⁴ Principally the following factors have been identified by Omstead and Stavins (2005) as being instrumental in shaping investment decisions in the power sector:

- The particular international policy mechanisms employed by climate change policy architectures.
- The particular domestic policy mechanism employed to participate in international climate policy architectures.
- The stringency and time horizons of emissions reductions required by policy architectures.
- The sector-specificity of international and domestic policy mechanisms.
- The current mix of fuels used in sectors that are affected by international and domestic policy mechanism.
- Demand elasticities and substitution possibilities among regulated fuels and technologies, and between regulated and unregulated fuels and technologies.
- Pre-existing distortionary taxes and subsidies affecting regulated fuels and technologies, as well as any such distortions introduced ex-post.
- The relative exposure of a country's energy market to domestic and international price fluctuations.
- The relative rate of abatement cost-reducing technological change in GHG emitting industries and activities.

Since regularity and economic risk are key criteria in making energy technology investment decisions, climate change policies should focus on mitigating exactly these risks with regard to nuclear power plants (NPPs). Issues such as management and disposal of spent fuels and other radioactive waste, the safe operation of NPPs, and proliferation concerns, are all important aspects to improve nuclear power as an option for generating electricity (and improve public perception). But these are issues of domestic and/or international policy making of a different thematic level not related to climate change, and indeed in part are issues/decisions of national sovereignty. In this regard the report on the 9th session of the Commission on Sustainable Development (CSD-9) concludes that the choice of using nuclear energy rests with countries, and so their judgment on the benefits of nuclear power with respect to sustainable development (UN, 2001). In keeping with CSD-9 climate policy should consider nuclear power with regard to its inherent climate benefits, enabling countries to make an independent judgment on the desirability to employ nuclear power as climate change mitigation technology.

Climate change policies can however lessen the regulatory and policy risk, as well as provide alleviation against the high-capital cost and long-lead times of NPPs. Table 1 provides a matrix of technology-associated risks for a range of power plant types. The nature of the risk profile is different for each energy technology, and investments in new capacity need to be carefully balanced against all technology-associated risks (IEA, 2005). In this regard, it is important to stress that economic and market conditions vary across countries and regions and with that the financial preference for particular technology options (which in fact is also dependent on the particular circumstances of the investor) (IEA, 2007).

The matrix highlights that nuclear power (on balance) scores higher/worse with respect to unit size, capital cost, lead time and regulatory risk compared to most other energy technologies, thereby worsening its investment attractiveness and making it less flexible than, for example, CCGT. By way of contrast, nuclear power fares well in consideration of fuel prices and carbon dioxide emissions consequently reducing the fuel price risk element. However, nuclear power is more vulnerable than its competitors with regard to capital costs and construction time overruns (thus increasing the economic risk). For example, an overrun of 10% on the capital cost and/or construction phase of a gas combined cycle plant would have a relatively modest effect on the project costs, whereas a similar overrun on a nuclear project would be much more economically damaging. Similarly, it is far more difficult to be confident of power prices (i.e. the source of

revenue) over long periods of time, which is why technologies with short lead times such as CCGT are favourable over those with long-lead times.

However, climate change policies can improve the relative attractiveness of nuclear power by either providing financial incentives that outweigh the risks associated with bad scores or by worsening the relative investment attractiveness of technology competitors. Obvious contenders for the former would be long-term policy frameworks that provide nuclear power with regulatory stability, and the acknowledgment of nuclear power as an eligible technology to generate carbon credits. For the latter, carbon taxes or emission targets would both increase the marginal cost of production of fossil fuel based power plants and thus improve the relative cost of nuclear power.

The pricing of carbon emissions through taxation or tradable permits, however, only improves the relative cost of nuclear power once the plant is generating electricity. Because NPPs have long-lead times, the aforementioned market based mechanisms do not offset the risks associated with its high up-front investment cost. However, theoretically carbon credits could be used to mitigate nuclear power's capital risk if carbon credits can be provided up-front. This could be achieved through a system of put-options whereby a government buys the option to purchase the project specific carbon credits at the start of the construction (or even planning) period.

A more detailed analysis is provided in the following sections with regard to specific post-2012 policies.

3. Nuclear power and the Kyoto Protocol

Before analysing future architectures – in the light of their consonance with nuclear energy – the exclusion of nuclear power as an eligible CDM/JI technology under the KP is discussed. This serves to demonstrate three points. First, that the provision of a stable regulatory framework and the minimization of the price/fuel risk can facilitate the investment in clean technologies. Second, that the inclusion of nuclear energy technologies as a CDM/JI eligible technology is unlikely to have led to any additional investment activity for nuclear power. Third, long-term policy-cycles/commitments are crucial to minimize the regulatory risk of nuclear investment.

Currently, nuclear power projects are excluded from JI and the CDM. These exclusions were part of the *Bonn Agreement* of the KP, arrived at in July 2001 at the extended sixth conference of the parties (COP-6bis), and were formalized in the *Marrakech Accords* at COP-7 later that same year, stating that Annex 1 Parties “are to refrain from using CERs generated from nuclear facilities” to meet their commitments under Article 3.1.

The KP has, as of October 2007, led to over 800 registered CDM projects, most of which are in the energy industry. While for the moment the effectiveness of the KP in supporting the uptake of clean technologies in non-Annex 1 countries is ignored, it is evident that the CDM *has* resulted in project implementation that – in accordance with the CDM methodology – would not have arisen otherwise. However, it is important to stress that at present the regulatory framework provided under the KP terminates after 2012. Therefore, the KP benefits projects that have sufficiently short lead times to accrue CERs over a time period that makes the investment

worthwhile. In theory, eligible projects are able to accrue CERs from the year 2000 to 2012. For some renewable projects, such as wind turbines or biogas digesters, where planning and commissioning can be done within a year or two,⁵ the CER revenue, which could in the ideal case be received for over a decade, can add significantly to project viability (in particular since capital depreciation may be completed).⁶

However, the construction of NPPs from its initial conception to project completion typically takes at least 7–10 years. Let us assume now that nuclear energy is eligible under CDM/JI. Even then it is inconceivable that investors would have invested in NPPs prior to February 2005 (KP came into force), because of the uncertainty and associated investment risk of the KP ever coming into force. Therefore, the earliest possible date for a CDM-eligible NPP to come into operation would have been in the final year of the first-commitment period of the KP (i.e. 2005 + 7 years)—not enough to reduce the investment risk!

It is therefore evident that investment decisions crucially hinge on the time-span throughout which low-carbon technologies benefit from a trading/crediting arrangement. For example, a study by the IEA indicates that emissions trading (ET) and carbon allowances can significantly alter the merit order of existing power plants to the advantage of low-carbon technologies, but only if *long-term* incentives or carbon markets are created (Reinaud, 2003).⁷ Therefore, an ET system that operates on short time scales, such as the KP, is unlikely to provide the long-term investment security needed by investors to invest in plant technology that have long-lead times and/or high-capital requirements. Typically, the electricity sector needs a coherent and consistent framework, which reflects the economic lifetime of the industry's investments in plants and infrastructure. Therefore, in order to remove the uncertainty regarding future obligations after 2012 (i.e. regulatory risk) clear signals from policy-makers on post-2012, are necessary to spurn significant investments in low-carbon technologies.

Evidently the time frame of the first-commitment period does not coincide with that of nuclear energy investment decisions. Therefore, if nuclear energy were to be allowed as a CDM/JI eligible technology in a post-2012 climate-architecture, commitment periods must be structured in such a way that provide long-term certainty over a period of at least 15 years so that NPPs can be developed and receive monetary carbon benefits to improve discounted cash flows in the early years of operation.

While the provision of long-term commitment periods has the potential to enable better investments in existing low-

⁵ While wind turbines can be constructed quickly (from an engineering point of view), in several jurisdictions the planning and sitting process has been controversial – such as Australia – resulting, in some cases, to construction delays upwards of 5 years.

⁶ Although according to the *State and Trends of the Carbon Market* 2005, developing a small to medium CDM project requires at least 2–4 years lead time from identification of the project to issuance of CERs (Cosbey et al., 2005).

⁷ The IEA report estimates that NPPs would be competitive with CCGT at €26 per tonne of CO₂ (including decommissioning), while renewable require CO₂ permits prices to lie between €30–200 depending on the specific technology.

carbon technologies they stifle the policy flexibility that political decision makers are often keen to retain. Shorter commitment periods add to policy flexibility since, for instance, in the light of new scientific evidence on climate change or breakthrough in clean technology development, new policy regimes can be adopted sooner without violating existing policies (which is crucial in ensuring policy credibility—an important building block of easing investors' fears over the strength of policy commitments).

4. Possible post-2012 architectures

All nations are sovereign and ratification of a future climate change agreement is voluntary. Any future agreement is therefore an intricate balance of environmental, ⁸ This is not

⁸ equity and economic concerns of participating nations (Wrang and Busk, 2005). Nonetheless, proposed post-2012 architectures can be clustered into three categories according to common characteristics. The balance between environmental, economic and equity outcomes of a post-2012 international climate change strategy are not fully reflected in the proposed clusters of architectures but are to a large extent determined by

- First, the breadth of participation: some architectures/instruments are unlikely to find sufficient mutual recognition to be a likely contender for a post-2012 regime. These are typically labelled closed-doors and presently include architectures such as long-term stabilization levels (e.g. contraction and convergence), harmonized policies and measures (PAMs), formula-based burden sharing, as well as aggressive action in the short-term (Wrang and Busk, 2005). On the contrary, open-door architectures commonly balance better the many different concerns of the UNFCCC member states. These open-doors include agreement on step-by-step reductions, continuation of modest emission reduction in the near future, bottom-up PAMs, and bottom-up political decisions on burden sharing (ibid.). In a post-2012 climate policy regime, that is characterized as being broad-but-shallow (i.e. wide participation but low on emission reduction commitments), only open-door frameworks are likely to emerge. On the contrary, closed-door architectures could emerge where wide participation cannot be achieved but few countries commit to significant emission reductions (i.e. narrow-but-deep outcome).
- Second, the specific timing and allocation of commitments by participants: potential commitments by member states are likely to be different depending on, for instance, their respective levels of development, past, present and anticipated emissions (absolute as well as per capita), as well as the potential and capacity to mitigate. For example, according to the *principle of common but differentiated responsibility*, Annex I countries initially voluntarily aimed at reducing emissions and later (under KP) adopted binding absolute emission targets. Similarly, non-Annex I countries could move into commitments in a staged fashion but delayed compared to Annex I countries and differentiated among them according to their responsibility. This step-wise integration of non-Annex 1 countries into assuming responsibility is typically referred to as multi-stage approach.
- Third, the compatibility of policy instruments: the architectures/instruments discussed here are not mutually exclusive, but in many cases complementary. Indeed, the combination of several mechanisms is likely to lead to an improved balance in achieving environmental, equity and economic goals. The KP for instance, combines elements from all three cluster-groups discussed below.

only helpful in providing an overview of the type of architectures that have been discussed in the literature, but also as a means of simplifying the great variety of approaches, since some are *hybrid*, combining elements of all three clusters. It is also important to note that the description of probable post-2012 strategies – as presented here – is limited to identifying the compatibility of providing an enabling environment for nuclear power development only. More complete and elaborate discussions – in particular with regard to, for example, implementation, monitoring and compliance concerns, and political acceptability – can be found in the references provided throughout the text.

Principally architectures can be grouped into three different sets as previously proposed in a similar fashion by Höhne and Lahme (2005), Omstead and Stavins (2005), and Wrang and Busk (2005):

1. Targets and timetables (T&T)
2. Policies and measures (PAMs)
3. Adaptation, technology cooperation and transfer

In addition to these three groups of architectures a *fourth* arrangement outside of the Kyoto scheme, the international agreement *Asia-Pacific Partnership for Clean Development and Climate*, established on July 28th 2005, will be presented. Although at this point, the six member states to this agreement (The United States, Australia, the People's Republic of China, India, Japan and South Korea) understand this partnership as being *complementary* rather than a substitute to the UNFCCC process, it is not inconceivable that an approach of this kind may form the basis of a post-2012 climate strategy.

4.1. Targets and timetables

This section briefly outlines prominent T&T approaches as identified in the literature. T&T (i.e. quantified and time-bound emission reductions) can be reached by employing a variety of instruments, across sectors and GHGs, such as the flexible mechanisms defined under the KP or other domestic command and control (C&C) and/or market based instruments (MBIs). But essentially each country can determine its own strategy in meeting the KP commitments. Emission targets can be designed in several ways. The most important difference is between absolute emission targets or flexible emission targets.

4.1.1. Absolute binding national emission targets (with/without price cap)

Absolute binding national emission targets commit countries to keep their absolute domestic GHG emissions in a target year (or period) below a fixed amount relative to a pre-defined base-year. A variation of absolute emissions targets can be introduced by allowing an unlimited number of additional emission rights at a fixed price (often referred to as “price cap” or “safety valve”). This would ensure that emission reductions and the associated abatement costs do not exceed the price cap.

4.1.2. “No-lose”, “one way” or “non-binding” targets

A no-lose architecture is an add-on to architectures with binding absolute emission targets and aims at taking on board countries without such commitments. In no-lose architectures countries without binding emission targets can negotiate a target, which allows them to sell emission reductions equivalent to the difference of the actual emissions (if lower than the target) and the target value. However, no additional emission certificates have to be bought, if the target is not met. Participation is therefore advantageous due to the possibility of economic windfall. As a variant, emission rights could be discounted when sold (e.g. at 50% of market rate) to provide an incentive for countries to take on an absolute target, where they would not be discounted.

4.1.3. Intensity or dynamic targets

An intensity target sets a domestic *emission intensity* target at a fixed amount in a target year. Emission targets are expressed dynamically, the most common intensity target being emissions/GDP. Dynamic targets aim to reduce the uncertainty in emissions associated with variable rates of economic performance and are therefore a more flexible tool than binding targets. Intensity targets are more likely to be reached through the introduction of domestic taxes and regulation of key GHG emitting sectors, though the overall economic cost and economic implications of industrial restructuring should be considered. However, as long as GDP grows faster than the intensity target falls, absolute emissions will continue to rise.

4.1.4. “Dual” or “dual-intensity” targets

An alternative to absolute binding emission targets would be to set two targets: a *selling target*, below which emission entitlements can be offered and sold in a carbon market, and a *buying target*, above which emission rights have to be bought. A country achieves the overall target, if emissions fall in between the two boundaries. The aim of such an approach is to take into account the uncertainty of future emissions (Höhne and Lahme, 2005).⁹

4.1.5. Sector targets

The goal of sector targets is to avoid competitiveness concerns across countries by applying the same rules for one sector to all countries. Several variations of sector targets are under discussion. Generally sector approaches would set absolute (emission-based) or relative (intensity-based) targets by sector—typically those that are energy intensive and together make-up the majority of national GHG emissions. Emission-based targets could be reduced emissions or a long-range zero-emission commitment over a certain time period. Intensity based targets are commonly based on intensity of production (e.g. GHGs per MWh of electricity generated), or on a

performance standard (GHG emissions per person kilometre by car).¹⁰

4.1.6. Extended CDM (sector crediting baseline)

Another option for non-Annex I countries would be to extend the CDM from a project-by-project mechanism to include also sector-wide national emission reduction. This means that quantifiable reductions as a result of specific sector policies can generate certified emission reduction. The amount of the reduction credits would be the difference between the sector's baseline level and the actual level. Any transfers would take place only after verification by an independent entity. Such projects could also be implemented unilaterally without an investor country.

4.1.7. Implications for nuclear power development

Targets and timetable approaches have the potential to reduce the economic and regulatory risks of nuclear power investment.

The economic risk can be reduced either because GHG emitting power plants face additional cost through MBI or C&C measures (so that the emission reduction target can be reached) and/or because flexible mechanisms allow nuclear power to generate carbon credits which subsequently can be sold to market participants. Indeed, the imposition of a carbon penalty increases the fuel price risk of carbon technologies in the absence of a cap on the permit price level, thereby increasing the relative attractiveness of low-carbon technologies. While a price cap provides greater certainty on the maximum abatement cost penalty it would also be lower which reduces the monetary carbon benefit of NPPs.

Of course, key is the level of the abatement cost or the price of a carbon permit and will largely depend on (a) the degree to which countries commit to mitigate and (b) the size and composition of the market, and (c) which measures/technologies are eligible for carbon mitigation/credits and their specific abatement cost. If the target is set at a level that leads to high abatement costs, and if long-term commitment periods are guaranteed, then the long-run marginal cost of low-carbon emission technologies, such as NPPs, may compete with fossil fuel generation and lead to new investment. However, the choice of domestic instruments employed to reach this target (e.g. taxes, standards, etc.) will affect the both level and the extent of any economic advantage NPPs might gain.

In countries without targets, NPPs attract investment based on standard economic merits, unless they are allowed as JI/CDM technologies in which case the anticipated price of carbon and the time period of the commitment period will prove essential.

The regulatory risk to investors could be lowered by having nuclear energy specifically inscribed as an eligible carbon mitigating option in order to help reach national emission T&T—especially if the commitment period stretches at least over 15 years (or possibly shorter but

⁹ Dual or dual-intensity targets were conceived as providing an incentive for participation from non-Annex 1 countries, and not as a way of providing flexibility for such countries to reduce GHG emissions. From a regulatory point of view the concern is that with dual targets CDM/JI projects could easily lead to double counting/selling of GHGs emission savings, and additional rules would be required to prevent this.

¹⁰ Sector targets could be differentiated according to national circumstances, either according to the state of the sector, or according to non-sector-related criteria such as level of per capita emissions, GHG emissions per GDP, etc. Sector targets could be defined either on a global level or only for individual newly joining countries. Sector targets could also be binding or “no-lose”.

follow-up schemes need to be certain to create cyclical investment incentives), which for capital intensive power plants with long-lead times is needed to recoup the majority of investment (IEA, 2007). The credibility of such a policy ought to be further strengthened by commitments from national governments that chose nuclear power as a mitigation tool to ensure investors that this policy will not change during the commitment period. Reducing regulatory risk, may in turn lead to improved financing terms and conditions which positively feedback on the economic competitiveness of nuclear energy.

4.2. Policies and measures

PAMs typically come in two forms:

- Instrument-based PAMs (domestic action).
- Harmonized PAMs (international action).

PAMs can be perceived as an instrument that can be used by individual countries alone in order to comply with an emission target, while harmonized PAMs can be implemented by a group of countries together, and with the aim to avoid a national competitive disadvantage (Wrang and Busk, 2005). Amongst the most common PAMs are two *Command and Control* (C&C) approaches and two *Market Based Instruments* (MBIs). These measures are, of course, not mutually exclusive but can be implemented jointly.

4.2.1. Technology and performance standards (C&C)

Domestic or internationally harmonized *technology standards* specify the method, and often the particular equipment that regulated entities/industries must use in order to achieve emission reductions (Omstead and Stavins, 2005). Typically, energy intensive industries that generate substantial carbon emissions, such as iron and steel, petrochemicals, paper and pulp, non-ferrous metals, non-metallic minerals and the power sector, would be included in such a scheme. A coordinated/harmonized technology standard would require that all participating nations impose the technology standard for the respective industry sectors. With sector specific technology standards it is the abatement cost or the cost of technology upgrade for new and or existing power plants that can improve the economic competitiveness of generating technologies not affected by this measure. Since technology standards are rigid, in a sense that it affects participants equally without allowing for economic efficiency, they can impose significant cost on target sectors and preclude more innovative, effective or lower cost solutions.

Performance standards, on the other hand, set emissions reduction requirements for all regulated entities, but allow some latitude in the particular method or technology with which the requirements are met. In its simplest application, performance standards set uniform reduction requirements for all firms, while a coordinated/harmonized performance standard would stipulate that all participating nations enact the standards at the same level of stringency (Omstead and Stavins, 2005).

The extent to which the imposition of technology standards can stimulate the development of new build NPPs

depends on the measure, as well as the time frame over which the measure pertains and whether it is made more stringent over time. For example, legislating the obligation to introduce carbon capture and storage for all new build fossil fuel power plants (perhaps initially exempting cleaner technologies such as CCGT) may certainly create an investment environment conducive for new build NPPs for base load supply in the electricity sector, depending on relative costs. Performance standards can potentially trigger investment in low-carbon energy technologies but this will depend on the marginal abatement costs and the time period over which performance standards are legislated. For, example the imposition of stack GHG emission targets per kWh for newly built power plants, may well require additional expenses for carbon capture and storage facilities, which would raise the overall-cost significantly and improve the competitiveness of NPPs. As with technology standards, the duration and stringency of the regulation will affect the amortized abatement cost that must be compared with the long-run marginal cost of NPPs.

4.2.2. Carbon taxes and emissions trading (MBI)

Domestic taxes to achieve GHG emissions targets might be assessed on each unit of carbon emissions that each source generates, so that sources reduce emissions to the point, at which marginal abatement costs are equal to the tax (Omstead and Stavins, 2005). Taxes might also be levied on the carbon content of fossil fuels such as, coal, petroleum, lignite and natural gas. A coordinated/harmonized tax would stipulate that all participating nations tax carbon emissions at the same rate. As in the case of uncoordinated domestic carbon taxes – when used as instrument based policy – it is likely that the tax rate would need to be negotiated periodically based on the effectiveness of the tax in reducing emissions (or based on new scientific data regarding the necessary amount and pace of abatement, as it becomes available). In order to achieve emission reductions, participants of a harmonized carbon tax scheme need to agree not to adjust other tax codes so that the carbon effect of the carbon tax is not undermined (Omstead and Stavins, 2005).

A domestic *tradable permit system* would issue carbon rights to regulated entities, typically energy intensive industries such as, refining, steel, pulp, electricity sector, etc. The total quantity of rights would be equal to the country's domestic GHG emission target. Typically, permits would be either distributed for free based on historic emissions (i.e. grandfathered) or by auction. Regulated companies that keep emissions below their allocated target can sell surplus permits to companies that find the carbon market price cheaper than their own abatement cost. Therefore, low abatement cost companies are typically net sellers of permits, while high abatement cost firms would be net buyers.

The degree to which CO₂ taxes can change the investment behaviour to favour new build nuclear energy technologies depends on the CO₂ abatement cost, the level of the CO₂ tax and crucially the duration over which the tax will be applied.

In countries with binding targets, stimulation for investment in NPPs depends on the price per permit, the reduction target of regulated sectors and their respective abatement costs, as well as the duration of the commitment period. In countries without binding targets, but that could supply

permits through certified emission reductions¹¹ from clean technologies such as nuclear power, the important parameters to stimulate investment are the anticipated price per permit and the duration of the permit market accepting permits from these new investments. Short-term carbon markets, as presently established under Kyoto's flexible mechanisms, will not suffice to stimulate investment in new build nuclear (see Section 3 and especially reference to the IEA study).

Policy credibility is equally important since investors require certainty that a policy instrument meets its design specification and is not altered or scrapped prior to its design life.

4.2.3. Sustainable development policies and measures

In return for Annex I countries complying with quantified emission targets, non-Annex I countries could agree to implement a set of PAMs which support their sustainable development, especially with regard to improving GHG emissions. Beginning with a development master-plan a set of climate related PAMs are designed. Non-Annex I countries could receive support from countries with emission targets to aide in the implementation of these policies. SD PAMs could be developed in such a way as to offer a solution between non-quantitative and quantitative approaches: opening the PAMs to trading would offer potential economic rewards from implementation (Philibert, 2005). It is may be likely that SD PAMs help make a stand-alone economic case for NPP development, where the development of nuclear energy technologies is economic or being considered for other reasons such as security and diversity of supply, air pollution mitigation, etc.

5. Adaptation, technology cooperation and transfer

Adaptation measures could also be viewed as part of an international commitment. Developed countries could, for instance, commit themselves to contribute to Adaptation

¹¹ Certified emission reductions can, under the KP, be garnered through the CDM or Joint Implementation. A similar mechanism could be employed in post-2012 architectures. The CDM is integral to the KP and allows industrialized countries to claim emission reductions from investments in mitigation projects in developing countries. Developed countries can thus use the emission reductions generated by the CDM projects to meet their own emission targets. The advantage of the CDM is threefold. First, projects contribute to meeting the emission reduction commitments. Second, they help developed countries to comply with their commitments cost-effectively. Third, CDM projects assist the developing countries in achieving sustainable development through transfers of environmentally sound technology and know-how. JI provides opportunities for developed countries to earn emission reduction units when helping to finance mitigation projects in another developed country. The investor country can use the emission reduction units generated by the project towards meeting their own commitment. The JI mechanism carries the same triple benefit as the CDM. Essentially JI and CDM are based on the same mechanism and principle but different in terms of the implementer and recipient country.

Funds, while developing countries can commit to mainstreaming adaptation into their sustainable development strategies. A range of technology cooperation and transfer designs exist to facilitate the diffusion and application of low-carbon and carbon sequestering technologies.

5.1. International collaborative technology approach

It is frequently argued that a cap and trade regime, as currently exercised under the KP, will not be sufficient to induce the technological innovation necessary to prevent climate change in the long-term. While the price signal created by carbon markets is sufficient to foster emission cuts using existing technologies, it is not providing sufficient impulse to justify significant R&D investments in nascent technologies, which will need to become available if more significant GHG emission reduction were to be achieved in the future (Sugiyama et al., 2004).

Coordinated collaborative technology agreements would spell out approaches to funding research and development, support for market development (e.g. subsidies, assured market shares), regulatory reform to facilitate uptake and demonstration projects in sectors that have high potential for low-cost but high-impact solutions (Cosbey et al., 2005). Another approach to technology agreements would commit countries to technology-related sectoral targets, and then cooperate toward such goals in the fashion described above (ibid.).

Sugiyama et al. (2004) suggest that there is an opportunity for treaties between regional and/or likeminded partners to create niche markets for technologies that are of mutual interest. The cooperation on energy conservation between China, Japan, and other Asian countries, as well as the cooperation on geological carbon storage among major fossil fuel producers such as US, Canada, Norway, Australia, Russia and Saudi Arabia are just two such examples.

All else being equal, significant investment in collaborative technology research is not likely to have an impact on investment decisions in the short-to-medium term in the energy sector, but can accelerate the learning rate and market application of technologies in the future. For example, the European Pressurized Water Reactor (EPR) development project, conducted as French-German cooperation in conjunction with Framatome ANP, as well as EDF and German electric utilities, has resulted in an improved NPP design (e.g. improved safety, safe-guards, and economics) that is currently under construction in Olkiluoto, Finland. Ongoing collaborative research on Generation IV¹² reactors between the

¹² In 2002, the US led the formation of a 10 nation (plus the European Union) organization, the Generation IV International Forum (GIF), to lay out a path for development of the next generation of "nuclear energy systems that can be licensed, constructed, and operated in a manner that will provide competitively priced and reliable energy products while satisfactorily addressing nuclear safety, waste, proliferation, and public perception concerns. The objective for Generation IV nuclear energy systems is to have them available for international deployment about the year 2030, when many of the world's currently operating nuclear power plants will be at or near the end of their operating licenses" (DOE, 2002).

European Union, the US, Japan, Brazil, Argentina and others aims at further improving nuclear safety, economics, proliferation resistance, waste creation and natural resource utilization.

5.2. Adaptation

It is projected that some of the most severe impacts of climate change will fall on developing countries, which are least able to cope with these consequences (Cosbey et al., 2005). The Third Assessment Report of the IPCC defines adaptation as “adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts” (IPCC, 2001). Broadly speaking, adaptation requires the provision of financial funds, disaster relief and capacity building that is additional to existing official development assistance by donor countries. Indicative estimates put the cost of adaptation somewhere between US \$10–100 billion p.a. (Blok et al., 2005). To help countries adapt to the adverse impacts of climate change, the Global Environment Facility – under the guidance of the UNFCCC – supports projects that reduce countries’ vulnerability to climate change impacts and helps them build adaptive capacity. So far, four funds have already been established (GEF, 2005):

1. Special Climate Change Fund.
2. Least Developed Country Fund.
3. Adaptation Fund.
4. Strategic Priority on Adaptation.

While of course adaptation has an important role to play in meeting the challenges of climate change, the Adaptation Funds do not focus on the accelerated uptake of certain technologies but rather aim at preparing society to cope with a changing natural environment.

5.3. Asia-Pacific Partnership for Clean Development and Climate

The United States, together with Australia, China, India, Japan, and South Korea have established the international agreement *Asia-Pacific Partnership for Clean Development and Climate* (AP-6) on July 28th 2005 in order to accelerate emissions reductions in the energy sector and to foster sustainable development outside the context of the KP. The intent is to (a) develop, deploy and transfer existing and emerging clean technology; (b) meet increased energy needs and explore ways to reduce the GHG intensity of economies; (c) build human and institutional capacity to strengthen cooperative efforts; and (d) seek ways to engage the private sector in these processes. This partnership aims to help each country to meet nationally designed strategies for improving energy security, reducing pollution, and addressing the long-term challenge of climate change.

Areas for collaboration may include, but are not be limited to: energy efficiency, clean coal, integrated gasification combined cycle, liquefied natural gas, carbon capture and storage, combined heat and power, methane capture and use, civilian nuclear power, geothermal, rural/village energy systems, advanced transportation, building and

home construction and operation, bio-energy, agriculture and forestry, hydropower, wind power, solar power, and other renewables.

In addition, the agreement promotes long-term transformational technologies that could radically reduce emissions while promoting economic growth, including next-generation nuclear power (e.g. Generation IV), fusion power, hydrogen energy distribution, biotechnology and nanotechnology.

The AP-6 is based on voluntary practical measures. Since this is the case, it is inconceivable that private companies adopt presently more expensive clean technologies without the provision of clear financial and/or regulatory incentives. The AP-6 is therefore not likely to have an impact on investment decisions in the short-to-medium term but can accelerate the learning rate and market application of technologies if collaboration receives sufficient political will and financial support.

6. Conclusion

The aim of the above analysis was to identify whether proposed post-2012 architectures have the potential to facilitate the development of nuclear energy technologies. It revealed that while some architectures can improve the competitiveness of NPPs, others are unlikely to provide incentives for nuclear energy development (see Table 2).

Binding *emission target approaches* (with or without caps) as well as *extended CDM architectures* (build-on target architectures), have the potential to significantly improve the conditions for nuclear energy vis-à-vis fossil fuel technologies. However, two preconditions are the termination of the present moratorium on nuclear energy to qualify as a clean technology under the CDM/JI mechanism, and the creation of long-term commitment periods and lasting carbon markets.

Also, *electricity sector targets* (absolute or relative) could provide significant incentives for domestic NPP deployment if the resulting abatement costs are high enough, and the policies through which the targets are met (e.g. *carbon tax*, *technology standards* or *performance*) are long lasting.

The pricing of carbon through taxation or tradable permits cannot mitigate the high up-front investment risk of nuclear power. However, theoretically carbon credits could be used to mitigate nuclear power’s capital risk if they can be provided up-front through a system of put-options during the early stages of planning and development.

Less conducive for nuclear energy development are *no-lose* and *dual-intensity* targets which are non-binding, since they do not provide sufficient certainty over carbon revenues. These architectures are more appropriate on a national level rather than sector or project specific where carbon benefits would directly provide incentives for NPP development.

Sustainable development PAMs, *international collaborative technology approaches*, and the AP-6 are no more or less likely than the KP to provide short-term incentives to new nuclear deployment. However, in the long-term they may prepare the ground for NPP development, if they do not preclude it or reflect in regulations any hidden non-nuclear biases. Policies aimed at *adaptation* are not necessarily conducive to nuclear power (or any other energy technology) since it is not the

Table 2 – Post-2012 policy matrix

	Conductive			Less conducive			Not conducive (short to medium run)					
	Absolute emission targets (incl. cap)	Sector targets	Technology standards	Performance standards	CDM/JI and extended CDM/JI	Carbon taxes	No-lose targets	Dual-intensity targets	SD PAMs	International collaborative technology approach	Adaptation	AP-6
Abatement cost	-	<input type="checkbox"/>	-	<input type="checkbox"/>	-	-	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-	-	-
Carbon tax	-	<input type="checkbox"/>	-	-	-	<input type="checkbox"/>	-	-	<input type="checkbox"/>	-	-	-
Cost of technology standard	-	<input type="checkbox"/>	<input type="checkbox"/>	-	-	-	-	-	<input type="checkbox"/>	-	-	-
Permit price	<input type="checkbox"/>	<input type="checkbox"/>	-	-	<input type="checkbox"/>	-	<input type="checkbox"/>	<input type="checkbox"/>	-	-	-	-
Compliance period	<input type="checkbox"/>	<input type="checkbox"/>	-	-	<input type="checkbox"/>	-	<input type="checkbox"/>	<input type="checkbox"/>	-	-	-	-

= primary investment trigger and = possible investment trigger (conditional).

intention of this type of policy approach to direct energy infrastructure development

While it is evident (from the above analysis) that stable and long-term commitment periods can be key to providing a nurturing investment environment for clean technologies, especially those with long-lead times, such as nuclear power and carbon capture and storage infrastructure, they are associated with reducing policy flexibility. Yet policy flexibility can be an important asset since it allows decision makers to initiate policy responses faster in the light of new scientific evidence (with regard to climate change) or technological advances in novel GHG mitigation technology. Breaking long-term policy commitments may not only lead to significant sunk investments but also undermine policy credibility which is needed to win the trust of investors in future policy frameworks. Ensuring environmental outcomes, policy flexibility and policy credibility are part of an inseparable nexus that requires balancing its constituent parts. However, it appears that – given the long-term character of climate change and its associated impacts – providing a transparent and stable policy framework for up to 15 years ahead is unlikely to constrain the ability of governments to manage climate change impact risks (IEA, 2007).

Post-2012 climate change policy should aim at capturing all low-carbon mitigation options (both at the supply and demand side to provide technology flexibility), as recently exemplified by Pacala and Socolow's (2004) stabilization wedges, not foreclosing them. Ultimately, the choice of technologies to advance in both climate change mitigation and sustainable development is a sovereign decision suited to the domestic situation needs of countries, and global CO₂ reduction ambitions.

Disclaimer

This article is the sole responsibility of the authors and the views therein do not necessarily reflect those of the International Atomic Energy Agency. Any mistakes or misinterpretations are the responsibility of the authors alone.

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Daniel Weisser is Director Strategy Renewable Energy at Marquard und Bahls AG, Germany. Previously he has worked as an Energy Economist at the International Atomic Energy Agency and as energy specialist at IT Power Ltd., UK. Dr. Weisser has academic interests in climate change policies, low-carbon energy technologies/strategies and small island energy systems—areas to which he has contributed as author and editor of international academic journals, IAEA and UN-Energy publications. He has also acted as director, organizer and lecturer at capacity building activities with the aim to improve the strategic approach to sustainable energy planning and climate policy formulation.

Mark Howells is a planner and economist based at the International Atomic Energy Agency's Planning and Economic Studies section. His is involved in energy-environment-economic analysis, model development and training. Previously he leads the Energy Modelling Group of the Energy Research Centre (ERC) at the University of Cape Town. He has contributed to several national and international planning programs for member states. Mr. Howells has also reported to the UNFCCC as an international expert.

Hans-Holger Rogner is Section Head of the Planning and Economic Studies Section at the International Atomic Energy Agency. He is an expert in the application of systems analysis to long-term energy demand and supply issues and their underlying driving forces. Since 1993, he has been involved in the activities of the Intergovernmental Panel on Climate Change. The results of his research assist the formulation of long-term energy strategies and policy targets for national and international institutions.