Prospects for nuclear power in the 21st century: a world tour

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Abstract: Objectives and content of the journal special issue on 'Prospects for nuclear energy in the 21st century' are introduced. It is concluded that the main reasons for considering nuclear power in the national energy portfolios include hedging against supply security risks and high fossil energy prices in most countries, complemented by climate change mitigation in developed countries and by local and regional air pollution reduction in developing countries. Concerns over nuclear power include operation safety, nuclear weapon proliferation, economic performance, nuclear waste disposal and public acceptance. The relative importance of these factors diverges widely across regions and countries.

Keywords: nuclear power; global projections; greenhouse gas mitigation; energy security; nuclear safety and security; public acceptance.

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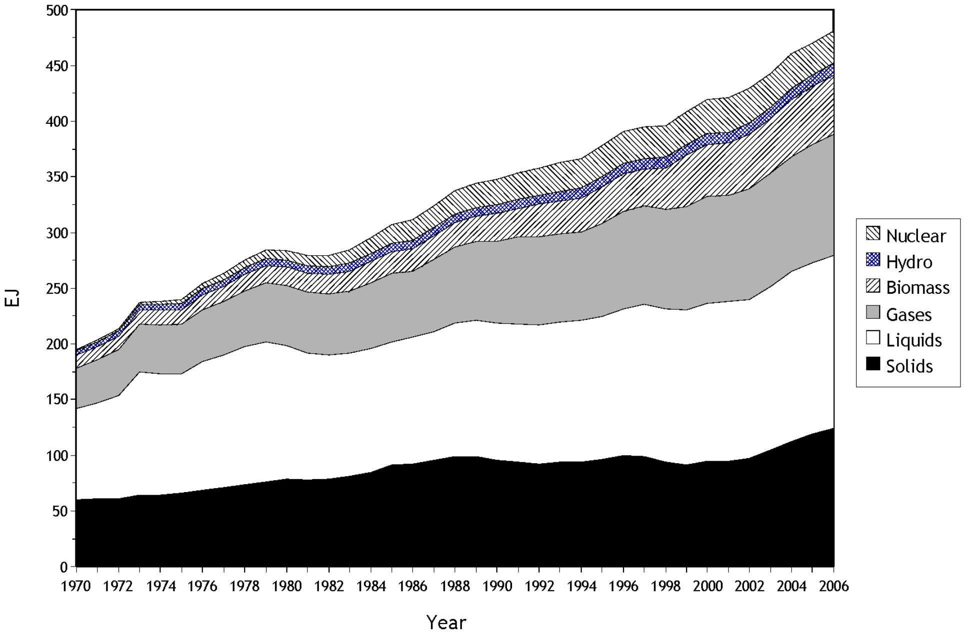
1 Context and objectives

Despite sustained efforts worldwide and at least partial success in many countries to increase the efficiency of extraction, conversion and utilisation of energy sources, the total energy requirement of the world has increased by a factor of 2.5 between 1970 and 2006, from 195 to 483 ExaJoule (EJ). Figure 1 shows the contribution of different energy sources to the global energy balance in this period. Albeit with some fluctuations, shares of solid and liquid energy sources have slowly but persistently declined while those of gases and biomass have increased. The share of nuclear energy has grown from just below 0.5% in 1970 to above 7% in the 1990s and declined to 6% by 2006.

Figure 1 Share of energy sources in the world total energy requirements, 1970–2006 (see online version for colours)

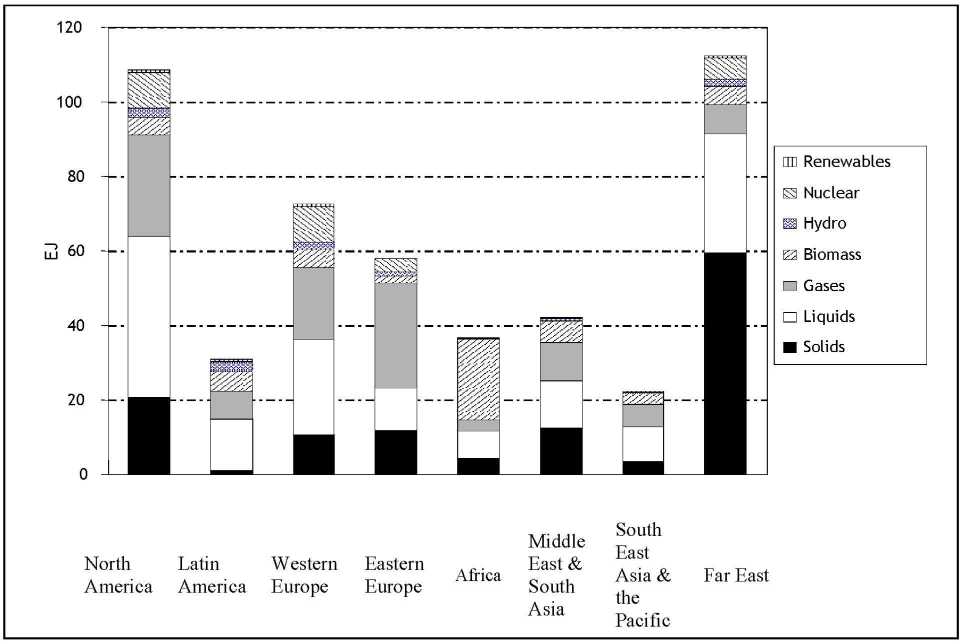


Source: IAEA (2007)

The relative importance of different energy sources varies widely across world regions. (Note: regions in Figure 2 and in Tables 1 and 2 encompass countries according to the IAEA (2007) country grouping. The rest of this introduction refers to regions covered by the papers in this special issue.) In 2006, solids provided more than half of the energy requirements in the Far East (including China, Japan and some smaller countries in East Asia in the IAEA country grouping) while their contribution was around 5% in Latin America. The share of nuclear energy was highest in Western Europe (about 13%) whereas it was not utilised at all in countries that belong to the IAEA region of South-east Asia and the Pacific (including Australia, New Zealand, Indonesia, Malaysia, Thailand and 20 other countries in this area). The total energy requirement by fuel type in different IAEA regions is shown in Figure 2.

Another characteristic trend over the past decades is the increasing share of electricity in total final energy. The relative importance of different fuels in electricity generation is also very diverse (see Table 1). Thermal sources dominate in the IAEA region of South-east Asia and the Pacific (88% in 2006), hydro provides more than half in Latin America, while Western Europe has the highest share of nuclear (29%). Key data of the nuclear power sector (Table 2) indicate that in 2006 the largest number of reactors was in operation in Western Europe, followed by North America.

Figure 2 Total energy requirements by fuel type in 2006 (see online version for colours)



Source: IAEA (2007)

Table 1 Fuel use (EJ) and fuel share for electricity generation by type of fuel in 2006

	Thermal[a]		*Hydro*		*Nuclear*		*Renewables*[b]		*Total*
Region	*Amount* (*EJ*)	*Share* (%)	*Amount* (*EJ*)	*Share* (%)	*Amount* (*EJ*)	*Share* (%)	*Amount* (*EJ*)	*Share* (%)	*Amount* (*EJ*)
North America	22.2	65.71	2.43	14.53	9.61	18.99	0.63	0.77	34.87
Latin America	4.4	38.28	2.46	58.31	0.33	2.61	0.32	0.81	7.54
Western Europe	15.6	52.32	1.72	15.86	9.56	29.14	0.53	2.68	27.37
Eastern Europe	17.4	64.95	1.12	17.21	3.51	17.80	0.02	0.05	22.01
Africa	4.9	80.01	0.35	17.74	0.11	1.84	0.04	0.41	5.40
Middle East and South Asia	14.4	82.42	0.64	15.51	0.20	1.57	0.02	0.50	15.28
South East Asia and the Pacific	5.8	88.17	0.26	10.73			0.21	1.10	6.28
Far East	32.6	75.65	2.04	12.50	5.70	11.52	0.47	0.33	40.83
World total	117.3		11.02		29.03		2.26		159.58

[a]The column headed 'Thermal' is the total for solids, liquids, gases, biomass and waste.

[b]The column headed 'Renewables' includes geothermal, wind, solar and tide energy.

Source: IAEA (2007)

Table 2 Nuclear power reactors in the world (end of 2006)

	In operation		*Long-term shut down*		*Under construction*		*Electricity supplied in 2006*
Region	*Number of units*	*Total MWe*	*Number of units*	*Total MWe*	*Number of units*	*Total MWe*	*Total MWe*
North America	121	111,867	5	3,633			880.7
Latin America	6	4,196			1	692	30.6
Western Europe	130	123,333			1	1,600	875.3
Eastern Europe	67	46,950			10	8,986	322.1
Africa	2	1,800					10.1
Middle East and South Asia	18	4,002			9	4,327	18.1
Far East	91	77,534	1	246	8	8,036	484.5
World total[a]	435	369,682	6	3,879	29	23,641	2,659.7

[a]Including the following data in Taiwan, China:

- 6 units in operation with total capacity of 4,921 MWe; 2 units under construction with total capacity of 2,600 MWe;
- 38.3 TWh of nuclear electricity generation, representing 19.5% of the total electricity generated.

Source: IAEA (2007)

During the five-decade history of nuclear power, sweeping changes have transformed virtually all factors directly determining its role in national energy portfolios and the main characteristics of the broader socioeconomic environment in which it has been operating. The high-tech image, the promise of an abundant, clean, safe and cheap energy source secured considerable popularity for nuclear power in most countries in the early decades. Practically all these features swung towards the opposite pole at least temporarily in the subsequent decades. One of the most important reasons for slowing the nuclear programmes in most OECD countries since the late 1980s was that reactors took too long to build and turned out to be uneconomic due to poor project management in construction and poor operating procedures. The slowing of electricity demand growth in the OECD in the 1980s and 1990s was an additional factor. The competitiveness of nuclear power was further undermined by the success of the gas-fuelled combined cycle heat and power technology backed by plentiful and cheap gas.

The two large accidents (Three Mile Island and Chernobyl) shattered the safety image. Policy responses to the accidents involved stricter and often unpredictably changing regulatory requirements and procedures that made nuclear power more expensive, but the resulting regulatory measures enhanced the safety of existing plants. Safety was further enhanced by integrating the lessons learned from the accidents into reactor design modifications and operating procedures. Moreover, actions taken by the operators to smooth procedures and keep reactors online helped decrease the number and length of unplanned stoppages and thus contributed to increasing the global average capacity factor by about 16% points in 16 years (from 66.8% in 1990 to 82.6% in 2006). This was particularly important in the context of power market liberalisation in many countries.

The 'clean' image was damaged by the perception of accumulating spent fuel and other nuclear waste. Fear of the bomb and of a nuclear collision between the two superpowers in the cold war era was a gloomy backdrop from the very beginning. Concerns about the development of nuclear weapons in combination with or under the disguise of nuclear power emerged (rightly or wrongly) somewhat later. In reality the development mainly happened in nuclear power states and preceded commercial nuclear power. The fear of nuclear terrorism is a more recent development. Despite all these mounting difficulties in the last two decades, reactor management and technological development efforts lead to improvements by the end of the 20th century. These improvements make nuclear power an important option to consider in responding to the challenges of the new century.

Nevertheless better management and technological improvements alone would probably be insufficient to turn many countries around on the use of nuclear energy. As a matter of fact, it was a suite of events and trends in recent years in the broader contexts that directed attention to nuclear power, including:

- *economic*: fast economic growth and rapidly increasing energy demand in large developing countries like China and India drastically raising fossil fuel prices.
- *political*: conflicts and war in key energy exporting regions pushing oil and gas prices even higher.
- *environmental*: increasing distress from local and regional air pollution in many developing countries, the rise of climate change to the top of the global environmental agenda.
- *energy-related*: in addition to the sustained high fossil fuel prices, supply security fears, competitiveness issues, concerns about the stability and reliability of energy services and alike.

In response to the revived economic and political interest in nuclear energy, a large number of studies have assessed a broad range of issues associated with the future of nuclear power, 'rising expectations' or 'nuclear renaissance' in recent years (MIT, 2003; Lillington, 2004; University of Chicago, 2004; Nuttall, 2005; Elliott, 2007). Special study groups in academia, national and international organisations in the energy field publish projections for nuclear power on a regular or occasional basis. These studies draw on regional information and many of them directly involve regional experts, but all are developed in the framework of global assessments. This global top-down approach has many virtues: uniform methodology, using the same data base, consistent assumptions, etc. However, the rich details of regional features, the historical and current social, economic and political intricacies of nuclear power and how they shape its future in geopolitical areas often remain hidden or are ignored altogether.

This Special Issue (SI) takes a different approach. We asked internationally recognised authors from 13 main world regions to assess the most crucial factors shaping the fate of nuclear power in their own areas and prepare possibly long term (beyond 2050), but at least a medium-term (up to 2030–2050) quantitative regional projections. Despite the flexible albeit explicit guidelines provided to the authors of the regional outlooks, the resulting papers comprise a diverse set. Some papers are good essays about the main factors shaping the future of nuclear power in the given region. They provide an in-depth discussion of the regional debates, the arguments for and against using nuclear energy but their numerical estimates are very limited. Other studies complement their qualitative assessment with official forecasts. Some authors review a diverse set of published regional projections and weight them against their own analysis of the future evolution of factors fostering or hindering the use of nuclear power to develop their own quantitative projections. Finally, other authors use quantitative scenario techniques and develop their own projections. The original intention was to extend the temporal horizon through the end of this century but this turned out to be an insurmountable challenge for most regions.

We believe that the emerging global mosaic is an interesting complement to the increasing number of recent studies looking into the future of nuclear energy. In addition to the quantitative projections, the papers also provide insights into the key issues and challenges for nuclear energy in different parts of the world. The short summaries of the papers in the next section do not intend to steal the thunder from them. On the contrary, the intention is to highlight their most interesting features in the global context and encourage the reader to study them in detail. Section 3 presents a short synthesis of selected themes cutting across the papers. We put the emerging global picture in the context of other recent nuclear energy projections in Section 4. The main points are summarised in the closing section.

2 A world tour into the future of nuclear power

As noted in the opening section above, technological R&D is an important factor that has made nuclear power a serious candidate among the options to respond to the mounting energy challenges of the 21st century. Clearly, nuclear R&D must not stop here. In the midst of many momentous uncertainties of the century ahead of us, the continuation of pervasive socioeconomic and technological changes can be taken for granted, but their exact directions and rates are impossible to predict. Moreover, other traditional and newly emerging energy technologies will also improve and the relative merits of competing technologies will determine how significant a role they will play. Scenarios are a convenient tool to cope with inherent unpredictability and provide guidance for action. Rogner et al. (2008a) take four of the best known and most widely used economy-energy-environment scenarios from the Intergovernmental Panel on Climate Change (IPCC, 2000) and conduct an in-depth analysis of the energy systems they depict with a view to the role of different energy technologies in them and with a special focus on nuclear energy in the four main world regions.

After setting the stage by defining the technology-relevant context with the four scenarios, Rogner et al. (2008b) estimate the required evolution of investment costs for nuclear energy to remain competitive in the range of futures portrayed by the scenarios. In addition to electricity, the authors also consider the potential uses of nuclear energy in hydrogen production, district heat generation and seawater desalination. They calculate the required cost targets by deriving learning rates from the energy system model Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE; see Messner and Strubegger, 1995) that was used in developing the original IPCC scenarios which serve as reference cases for this study. The results of these companion papers provide useful guidance for R&D planners and investors regarding how to make nuclear energy competitive under a wide range of possible medium- to long-term futures.

Our world tour takes us through 13 regions. We travel around the world eastward starting in Europe and make diversions to the South. Just as any scheme trying to group countries together into regions, our scheme also involves imbalances and compromises, largely based on the availability of information for and the inclination of regional authors to assess the nuclear future of geographically close but culturally and/or politically more distant countries. The geographical coverage of the regional papers differs from the IAEA regions discussed in Section 1. It is presented in Table 3.

We start our global tour in West and Central Europe (including all European countries outside the Former Soviet Union except the three Baltic countries), the region with large diversity in using nuclear energy. It includes countries heavily relying on this source in their electricity balance (e.g., France and Slovakia), states fiercely opposing the use of nuclear power even in their neighbour countries (e.g., Austria), and also countries with official phase-out schedules (e.g., Germany and Sweden) as well as countries that seriously consider introducing it (e.g., Poland and Turkey). The essay by van der Zwaan (2008) reflects the diversity in the nature and magnitude of nuclear-related concerns across Western and Central Europe. Given the large number of open questions and possible reversals of current introduction or phase-out policies, it is not surprising that the capacity projections derived from van der Zwaan's assessment show the largest difference between the low and high estimates among the quantitative regional projections included in this SI.

Table 3 Geographical areas covered by the regional papers in this SI

	Name	*Acron*	*Region or major countries*
1	West and Central Europe, Turkey	WCE	Europe – Former Soviet Union + Baltic States and Turkey
2	Eastern Europe and Caucasus	EEC	Ukraine, Belarus, Caucasus countries
3	Russia and Central Asia	RCA	Russian Federation, Central Asia
4	West Asia, North Africa	WAN	Asia west of Afghanistan, Middle East, Africa north of the Sahara
5	Sub Saharan Africa	SSA	All countries south of the Sahara
6	South-west Asia	SWA	Pakistan, Afghanistan
7	South Asia	SAS	India, Bangladesh, Sri Lanka
8	South-east Asia	SEA	Indonesia, Malaysia, Thailand, Vietnam, Philippines, Singapore
9	East Asia	EAS	China, DPRep Korea, Mongolia
10	Far East Asia	FEA	Japan, Rep Korea
11	South Pacific	SPA	Australia, New Zeeland
12	North America	NAM	USA, Canada, Mexico
13	Latin America	LAM	America south of Mexico

Acron = Acronym.

In our next region, in Eastern Europe and the Caucasus (EEC) covered by Purtov's (2008) paper, nuclear power is part of the Soviet heritage with all its blessings and curses in two countries (Ukraine and Armenia). Energy resource endowments vary widely across the region: the Ukraine has the most diverse resource base while Azerbaijan has the largest oil and gas reserves. Of the two countries with nuclear power, in Armenia the last unit still in operation is scheduled to shut down in 2011 that will lead to 60% of the country's electricity supply dependent on imported natural gas. Understandably, operation safety is the main nuclear-related fear in these countries but concern over the security of supply has been emerging recently as the major overall energy-related concern in all countries of the region. In response to supply disruptions in 2007 and to increasing gas prices, even Belarus, the country severely affected by the Chernobyl accident, is making determined steps towards introducing nuclear power in the next 10–15 years.

The next step towards the East takes us to the region involving the bulk of the Former Soviet Union: the Russian Federation and the five countries in Central Asia. Chebeskov and Kagramanyan (2008) present an outlook into the nuclear energy future of this region that is largely centred on the Russian Federation, a major player in global nuclear science and technology with ambitious domestic nuclear energy programmes. In this country, despite declining population and economic transformation towards less energy intensive industries, electricity demand is expected to increase by about 50% by 2025 and to double by 2050 relative to the current level due to increasing living standards. Moreover, high oil and gas prices provide the same motivation to increase the share of nuclear power in electricity generation in a major exporter of these resources as they do in importing countries, yet on the mirror side: gas substituted by nuclear in domestic power generation can be exported, making nuclear investments lucrative at the aggregated economic level. Currently there are no nuclear power stations in operation in the five Central Asian countries, but Kazakhstan might consider building new reactors in the next decades.

In all probability, the most challenging region for an assessment of nuclear prospects is the one spanning from West Asia (West of Afghanistan) across North Africa. The diversity of countries in terms of energy resource endowments and income levels on the one hand and the motivations for considering nuclear power on the other is the largest among all regions in this SI. Rogner and Abdel-Hamid (2008) find that the interest of the West-Asian OPEC countries in nuclear power is motivated by the same factor as that of the Russian Federation: considering the high international oil and gas prices, the opportunity cost (foregone benefits) of using these resources for power generation (instead of exporting them) far exceeds the costs of establishing a nuclear power programme.

The 43 countries in the region of Sub-Saharan Africa have many common features (large spatial extent and long distances between population centres, uneven and often remote location of resources) and share many problems and challenges (above all: retarded economic development and poverty). Kenny (2008) presents a long list of the social and economic impacts of unavailability of energy in the region. He also provides compelling arguments why small nuclear power reactors could be part of the solution to these huge problems in many countries of this region.

The next two regions, South-west and South Asia include countries in which civilian and military nuclear technologies were developed together in national R&D programmes. The paper by Mumtaz et al. (2008) on South-west Asia covers two countries: Pakistan with fast growing economy and energy needs in recent years and war-torn Afghanistan with ambitious development plans but great difficulties in implementation. Similarly to other developing countries, fast-increasing demand for energy to foster development and limited domestic fossil fuel resources are the main motivations to pursue nuclear power development in Pakistan. The motivations are the same in South Asia (including India, Bangladesh and Sri Lanka) (Grover, 2008) with about one fifth of the world's population, still increasing rapidly, and with fast-growing economies with enormous hunger for energy. Health-related impacts of traditional energy sources are also a major concern both in South-west and South Asia. Despite good hydroelectricity potentials and availability of coal in some countries in South Asia, nuclear power is expected to take an increasing role in the future.

It is worrying for the densely populated regions of South and South-west Asia, as well as for the rest of the world, that these two regions include countries with nuclear weapons but not parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). This fact limited their access to civilian nuclear know-how and probably hampered the development of nuclear power technology in the past. Finding ways to ease the proliferation concern in this region is an important aspect in fostering nuclear power development in the future.

South-east Asia has been on fast-track economic growth for decades and even the Asian financial crisis of 1997–1998 proved to be only a temporary derailment. Sustained economic development in the future will be accompanied by further increases in energy demand. Some countries (e.g., Indonesia and Vietnam) are well-endowed with fossil resources but even they consider including nuclear power in their supply portfolio. Thus the region has a number of countries that might be new entrants to the global nuclear power club in the next 10–15 years: Indonesia, Thailand and Vietnam. Interestingly, the Philippines, the country that completed a reactor in 1985 but never used it (just like Austria), seems to be further away from using nuclear power, perhaps for that very reason. Sudarsono and Weisser (2008) look into the region-specific issues and assess the nuclear prospects for the next few decades.

The East Asian region, practically China, has the fastest growing hunger for energy and electricity in the world. China has been installing about 100 GWe generation capacity in recent years and this trend is likely to continue for some time, driven by the unrelenting growth of the economy. Despite mega-scale hydro projects like the Three Gorges dam, fast-growing (albeit from a very low base) investments in other renewable sources and the increasing role of nuclear power, the bulk of the new generation capacity is still coal-based, probably with limited technical potential to add carbon-capture equipment in the future. Zhidong (2008) provides a comprehensive assessment of the region's energy needs and the potential role of nuclear power in it. In China, the four-fold increase of the nuclear generating capacity in just over a decade by 2020 is a staggering rate in international comparison but it comprises only a few percent of total annual electricity generation expansion in this country.

The Far East Asia region covered by Nagano (2008) includes two countries with mature nuclear power industries: Japan and the Republic of Korea. The two countries are similar in many aspects of socioeconomic development, in advanced technological capabilities in many industries and in energy resource endowments. Yet differences in some areas, like the rate of growth in energy demand or the socio-political issues surrounding nuclear waste lead to different prospects for nuclear power in the future.

In the South Pacific region (Matysek and Fisher, 2008), the two large countries have been able to cover their electricity needs from their copious domestic resource base: coal and gas in Australia, hydropower and, more recently, gas and coal in New Zealand. Nuclear energy is ruled out by current legislation in the latter, but it might enter the generation portfolio by 2025 in Australia should there be a major revision in current climate policy that would trigger cost increases for coal-based electricity. Since there is no serious sign of even the very preliminary steps towards introducing nuclear power anywhere in the region, putting non-zero values in our summary projection would be based on pure speculation.

After three decades of time-out in the USA and similar trends in Canada, nuclear power is vigorously back on the energy agendas in both countries. Mexico's nuclear prospects are more uncertain but the nuclear option is open even in the near term up to 2020. Hagen's (2008) paper about North America focuses on the two large countries because recent developments in national energy strategies and nuclear regulation open new opportunities and provide new incentives for nuclear power investments. To what extent the industry will be able and willing to use these opportunities is not yet clear but the initial responses in the form of licence applications and investors' expressions of interest is promising. The evolution of nuclear power in the USA and Canada is likely to have wide-ranging effects on nuclear development in Mexico, further south in Latin America and many other countries around the world as well.

Our world tour terminates in Latin America where the development of nuclear energy in the past has been heavily influenced by political turns, financial crises and other events beyond the energy sector. As a result, there are currently four operating reactors and an equal number of suspended nuclear power projects in the huge geographical region from south of Mexico to the Tierra del Fuego covered in the paper by Simbalista (2008). While the overall economic and energy sector features witnessed in other developing regions (increasing energy demand, security of supply, etc.) would motivate increasing reliance on nuclear power, the usual concerns related to its use (especially operation safety) are raised in Latin America as well.

In addition to the regional papers summarised above, a few thematic papers address issues that will be essential in the future of nuclear power. It is perhaps surprising that the availability of nuclear physicists, engineers and other experts as a constraint for fast expansion of nuclear power is not highlighted as a potential concern in the regional papers. Carlisle et al. (2008) discuss the many aspects of vanishing nuclear knowledge as a result of the three-decade decline of the nuclear industry in the USA. The knowledge-related prerequisites for a nuclear revival include education, research and development, adjusting the codes and standards to new developments in technology, and the recovery of records and data harbouring valuable information. The insights from their study might be relevant beyond the USA as well because bottlenecks in the availability of nuclear knowledge for technology development, licensing, construction, operation and regulation might be a problem in other regions with sluggish nuclear power sector in recent decades. Nonetheless, views in the broader community differ about how rapidly the pool of nuclear skills can be expanded to support a fast-growing nuclear industry.

Shea and Zentner (2008) provide a comprehensive picture of proliferation issues, the components of proliferation risk and various concepts of and approaches to proliferation resistance. They summarise current efforts in international technological development programmes to make future generations of nuclear power reactors more resistant to the diversion of nuclear material for clandestine purposes. Beyond the technological and fuel-cycle-related arrangements, however, political and legal instruments are likely to play an important role in preventing the proliferation of nuclear weapons.

At the end of our grand tour, we revisit the nuclear power technology issue that is addressed by Rogner et al. (2008a, 2008b) from the long-term competitiveness perspective. Cleveland (2008) provides a global survey of efforts to develop new reactor types and designs that involve steps towards fulfilling the competitiveness criteria and simultaneously easing the concerns (economics, safety, security, waste) raised in the regional studies. He takes a closer look at plant costs, high safety levels, proliferation resistance, and how they are conceived and implemented in major types of advanced plants: both evolutionary designs over the next decade or two as well as in innovative designs towards 2030. Considering the diversity and the relative importance of the different concerns and user criteria in different regions, it is highly unlikely that a universally applicable, single-best technology will appear over the next few decades. Although the many different directions of nuclear technology development may appear to be profligate to some, they are actually crucial for finding the proper solutions to the different challenges. At the same time, they demonstrate the eminence of science and ingenuity of engineering that are so essential for the future of nuclear power and its ability to fulfil the rising expectations to contribute to sustainable development in this century.

3 Common themes cutting across the regions

There are some clear patterns emerging from the regional pictures that confirm former observations of the global energy scene. A few of these patterns are highlighted in this section in two groups: the major socioeconomic factors that trigger countries to take a fresh look at nuclear power in different regions and the relative importance of the main nuclear-related concerns across the regions.

The strong performance of the world economy (around 4%/year real GDP growth rates) and, especially, of the developing countries (just below 7% annual average) in recent years has elevated tens of millions of people from poverty. This process was fuelled by energy and it simultaneously boosted the demand for energy. The world's total energy requirement in 2006 amounted to 483.23 EJ, 80% of which was of fossil origin (IAEA, 2007). There are two main risks emerging from recent trends: if the global energy industry is unable to satisfy the ever-increasing hunger of the world economy, growth rates might decline in the near term dampening hopes for reaching development targets in many countries. In contrast, if global energy demand will be met the same way it has been in recent years, environmental implications might dampen growth rates or even eliminate some of the development achievements over the medium and longer term. Countries in different stages of socioeconomic development still tend to emphasise one or the other side of this double-faceted feature of the development-energy-environment linkages and the potential role of nuclear power in resolving the dilemma.

Table 4 summarises the reasons for considering the introduction or expansion of nuclear power most frequently mentioned in the regional papers. Authors looking at the prospects for nuclear power in developing countries cite staggering increases in demand for energy in general, and electricity in particular as the main reasons for the increasing interest in countries already using and for the emerging interest in countries as yet without this technology. This is not surprising. As people are getting more affluent, they demand cleaner, safer and more convenient forms of energy and electricity is providing just that. Although at slower rates, electricity demand is expected to increase in developed regions as well, even in those with declining population numbers and modest economic growth rates.

Table 4 Reasons for considering to introduce or to expand nuclear power in the SI regions

Region	*Energy demand*	*Environment*	*Supply security*	*Health*
West and Central Europe, Turkey	Growing electricity demand	Major concern over CO_2 emissions	Increasing concern	
Eastern Europe and Caucasus	Growing energy demand	Some concern, increasing CO_2 emissions	Major concern	
Russia and Central Asia	Growing electricity demand	Increasing concern	Oil and gas export opportunities, long-term energy security	
West Asia, North Africa	Fast growing electricity demand	Emerging concern in Gulf countries	Oil and gas export opportunities	
Sub Saharan Africa	Energy shortage hinders development	Nuclear energy protects the environment more than other sources	Small power reactors enhance energy security, reduce transmission and transportation costs	Main concern; + gender equity
South-west Asia	Fast growing energy needs	Ecological problems associated with reservoirs; Asian haze	Serious concern	
South Asia	Fast growing energy needs far into the future	Fossil fuels causing pollution	Concern for a balanced energy mix and self reliance	Main concern; + gender equity
South-east Asia	Economic development, access, fast growing energy needs	Local and regional pollution; CO_2 not a concern yet, public opposition to environmental impacts of coal and hydropower	Increasing imports despite considerable domestic resources	
East Asia	Staggering demand growth	Local, regional, increasingly CO_2	2030: oil import 76%, gas import 52% of demand, energy mix	
Far East Asia	Korea: Demand further growing	Main concern	Main concern	
South Pacific	Gradual rise of electricity demand	Climate change-CO_2	Not a serious concern	
North America	Demand growth for electricity in USA–Canada, fast growth in Mexico	CO_2 (although USA rich in cheap coal)	Availability of resources oil and gas, especially in USA	
Latin America	Fast growing electricity demand	Increasing concern over ecological impacts of hydropower and CO_2 emissions	Increasing concern	

Entries are drawn from the regional papers in this SI. Blank cells indicate that the corresponding paper does not raise the issue.

The next frequently mentioned motivation is closely related to the above. The rate of infrastructure development in fossil resource extraction and delivery in key supply regions is lagging behind the fast-growing energy needs and this exerts a sustained upward pressure on international oil and gas prices. This in itself is a strong motivation for countries with high shares of imported fuels for their electricity generation to look for substitutes. Political conflicts in key supply regions exacerbate the price pressure and raise severe concerns over the security of supply per se, even at high prices. This is yet another reason for considering alternative electricity sources. Interestingly, developing countries tend to be more worried about the sustained high price level because it would severely increase their energy import bills, affect their current account balances and undermine the competitiveness of their export industries. In contrast, developed countries are more worried about the direct losses due to supply disruptions, probably because energy is a relatively smaller fraction of their total import bills and the energy content of their exports is lower.

The largest difference between developing and developed country interests in nuclear power, however, is related to environmental and health issues. Developed countries have for the most part eliminated the main sources of local (C_xH_x, ozone precursors) and regional (SO_x, NO_x) air pollution and their main environmental concern is climate change. While many developing countries also realise the negative impacts they would suffer from changing climatic conditions, many of them experience immediate losses from smog and acid deposition and some consider nuclear power as vehicle to tackle these problems. Direct energy-related health impacts are also much more severe in developing regions (indoor air pollution, traditional biomass).

There are several concerns associated with the use of nuclear power, but their relative importance varies across regions to some extent. Table 5 provides an overview based on the regional papers. Among these concerns, the most crucial one in shaping public perception is operation safety. This is the uncontested leader and the most frequently mentioned factor in the regional papers. Although opponents to nuclear power never miss an opportunity to scare the public with the dangers of nuclear power stations, the nuclear industry does not seem to be doing a very good job in explaining to the public that the reactor models on sale today that buyers are choosing from are very much improved since the time of the Three Mile Island and Chernobyl accidents. Fortunately, the industry is doing a much better job in technology development by incorporating passive safety features into new editions of the Generation III technologies and making them a basic feature of innovative designs in the future. In addition, the globalisation of operation experience in the nuclear industry is strengthening safety even further.

The regional papers show a remarkable disparity in the fears over operation safety between developed and developing countries. Safety concerns appear to be the most severe in Europe (both West-Central and Eastern Europe) in the long shadows of Chernobyl and in Japan fed by recent incidents, but also in Latin America with very few operating reactors and in the South Pacific (Australia and New Zealand) with no nuclear facilities at all. In contrast, safety issues cause less anxiety in South and South-west Asia with almost 20 reactors operating in densely populated areas.

Table 5 Concerns over nuclear energy in the SI regions

Region	*Economic*	*Safety*	*Waste*	*Proliferation*	*Public accept*	*U resource*
West and Central Europe, Turkey	Favourable and competitive with other sources	Main concern	Serious concern; exploring various methods of disposal, also NIMBY syndrome	Not an issue in the region but serious concern proliferation outside	Widely diverging acceptance across countries in the region; positive attitude is increasing in some countries	Very limited, but confident about global availability
Eastern Europe and Caucasus	Rising fossil fuel prices increase competitive advantage of NE	Main concern	Steps taken to resolve	Not an issue	Still not popular (Chernobyl)	Recoverable resources (Ukraine)
Russia and Central Asia	Export gas to benefit from high international prices	Some concern, but not hypersensitive	Motivation for new technology platform (closed fuel cycle)	Motivation for offering international fuel services including SNF management	Improving; Chernobyl effect declining	Motivation for new technology platform (closed fuel cycle)
West Asia, North Africa	Favourable	Reason for hesitation in some countries	Favourable conditions	Serious concern	Positive in most countries	
Sub Saharan Africa	Economics favourable, financing requires higher risk premia	Standards will need to be higher, needed trained manpower	Favourable conditions (geology, big empty paces, distance)	NWFZ, Treaty of Pelindaba is respected	Some opposition, but mostly public support	Large resources in several countries
South-west Asia	Favourable	Good	Preliminary work on disposal facilities	Non-NPT country; concern outside	Generally supportive	
South Asia	Good (no concern)	Good (no concern)	Partly motivates closed fuel cycle, not a serious public issue	Non-NPT hindered international cooperation; but 'not even an issue'	Positive, support for new build	Limited domestic, close fuel cycle; go for thorium
South-east Asia	Some, especially as long as domestic resources last	Part of concern, but no strong opposition	Part of concern, but not a serious obstacle in introducing NE	Countries are allies in ASEAN, afraid of generating suspicion; but adherence to Treaty of Bangkok	Major concern: public and political opposition, slowly changing to positive	

Table 5 Concerns over nuclear energy in the SI regions (continued)

Region	*Economic*	*Safety*	*Waste*	*Proliferation*	*Public accept*	*U resource*
East Asia	Needs preferential treatment (tax reduction, financing, quota purchasing)	Major concern	Primary concern	Not a concern	Currently not a problem	Limited domestic, therefore fast breeder reactors
Far East Asia	Favourable conditions in terms of capital availability and price competitiveness	Japan: concern after incidents	Japan: big social issue, Korea: easier	Problem in larger region (North Korea); analysed as common global concern	Key issue in Japan; positive in Korea	Major U importers, with enrichment facilities (Japan)
South Pacific	Not competitive without CO_2 constraints or penalties or without government support to manage risk	Not a concern, but international development in nuclear safety has an impact	Large space but states decide about policies and sites	Not an issue and strict adherence to NPT related export controls	Not popular, but only limited debate so far	Plenty of Uranium, major supplier to global U markets
North America	Improving competitiveness with coal	Response: strict regulation	Still a concern, despite large investments (Yucca Mt.)	Not an issue in the region	Acceptance good	
Latin America	Availability of investment funds	Main concern and lack of public information about nuclear energy		Good regional cooperation	Some local opposition	Very limited

Entries are drawn from the regional papers in this SI. Blank cells indicate that the corresponding paper does not raise the issue.

NIMBY: Not In My Backyard; SNF: Spent Nuclear Fuel.

The second most important factor shaping the public perception of nuclear energy is the risks associated with the interim storage of spent fuel and the long-term disposal of nuclear waste. Public fears associated with on-site storage are much lower than about reactor operation but information about the safety properties of wet (underwater) and dry storage facilities available to the public is still sparse. More severe public opposition is witnessed against interim and final repositories of high-level wastes in some countries. While the preparations of such facilities in Finland and Sweden are progressing well, in a Japanese prefecture merely the expression of interest in a feasibility study for a repository (with no binding commitment irrespective of the outcome) led to the replacement of the local mayor in the ensuing local elections.

Although nuclear power is not the vehicle, nuclear proliferation is an important and highly contentious issue in international politics. It appears to be a secondary factor in shaping public acceptance of nuclear power. Currently nuclear proliferation is an acute problem in only a few regions. Yet concerns over the risk of spreading nuclear weapons technologies and material to an increasing number of countries has overcast the history of peaceful use of nuclear power and will remain a potential stumbling block in its future development. With the emerging threat of terrorism in the early years of the 21st century, additional fears appeared: using nuclear devices or nuclear material in combination with traditional explosives (dirty bombs) or direct attacks on nuclear power plants or other nuclear facilities (e.g., by using airplanes). In addition to the thematic essay by Shea and Zentner (2008), several regional papers in this issue address various facets of the proliferation problem: Kenny (2008) notes that South Africa is the first and so far the only country in the history of nuclear weapons that built and then dismantled and destroyed nuclear bombs. Nagano (2008) compares different propositions concerning international fuel service arrangements with spent fuel take-back that would reduce incentives for countries to develop new domestic enrichment capabilities and make accounting for nuclear material easier.

The importance of electricity costs for consumers and thus the economics of nuclear power are closely related to income levels. In the household sector, beyond the lack of access to electricity (being unconnected), affordability (the price relative to income) is a severe obstacle for switching to a cleaner and safer energy form in many developing countries. In high-income countries, people are less sensitive to electricity prices. In Austria, for example, each electricity consumer could save, on average, €100/year by simply switching to another utility company offering lower rates, but less than 1% of the consumers did so in 2006 (Kischko, 2007). However, electricity prices are an important factor in shaping the international competitiveness of the business sector, especially that of electricity-intensive industries.

The economics of nuclear power needs to be addressed at two levels. First, the direct explicit costs of generating one kWh electricity levellised across the lifetime of the power plant and second, the social costs including all externalities (positive and negative side-effects not reflected in the price of electricity) that happen to be predominantly positive in the case of nuclear power. The costs of decommissioning and waste disposal are collected and accumulated through the operating lifetime of the power plant whereas the social benefits of avoided CO_2 emissions or increased supply security remain unaccounted for. In addition to regulatory uncertainties, both in the nuclear sector and in the electricity market in general, the unrewarded social benefits (equivalent to the gap between private and social costs of fossil competitors) represent another factor that discourages potential investors.

These issues are reflected in the regional papers as well. Nuclear power is not competitive with cheap coal in the absence of climate protection measures in Australia and it would need preferential treatment (tax reduction, financing, or regulated quotas for consumers) in China where the human health and other social costs of coal-based electricity are not reflected in the generation costs. Competitive positions against coal are improving in North America and Europe even in the absence of greenhouse gas (GHG) penalties or under preliminary CO_2 emission permit market conditions (see Ellerman and Buchner, 2006). The economics of nuclear power is estimated to be favourable even without GHG concerns in India (especially in demand centres far away from coal mines) and for small reactors in Sub-Saharan Africa. Expectations about the longevity of high oil and gas prices makes nuclear power a possibly lucrative investment both in importing countries (with increasing security of supply as a special bonus in addition to lowering total supply costs) and exporting countries (acquiring larger volumes of resource rents while obtaining (West Asian oil/gas exporters) or further developing (Russian Federation) technological capabilities for the post-hydrocarbon era.

As mentioned above, the relative importance of the four main concerns about nuclear power in shaping its public acceptance varies across regions and sometimes even across countries within a given region. In addition to the long-known nuclear divides in Europe (van der Zwaan, 2008), a good example of the latter is the Far East where public acceptance, especially the not-in-my-backyard (NIMBY) attitude, might prevent new builds at new sites in Japan whereas public opinion is reported to be positive in the Republic of Korea (Nagano, 2008). Other regional papers report good public acceptance in East Asia (China) and South Asia (India), improving public approval rates in North America (USA) and in the Russian Federation, but unpopularity in Eastern Europe (still an aftermath of Chernobyl) and in the South Pacific (no direct experience with nuclear power so far).

4 Nuclear prospects in this study compared to recent projections

Based on their assessments of the broad socioeconomic drivers and the specific nuclear-related factors summarised in the previous section, authors of the regional papers in this SI present quantitative projections at varying levels of detail and specificity. This section briefly compares these regional projections and the emerging global outlook with recent medium-and long-term regional and global projections.

Section 2 highlighted the main factors that are expected to drive future trends for nuclear power in the regions. The consolidated sets of quantitative projections are presented in Table 6. The numbers are directly taken or derived from the regional papers. Data in this table provide the starting point for comparisons with other projections.

Table 6 illustrates the diversity characterising the regional assessments in this SI: some authors prefer working with a baseline or central scenario while others specify the low and high boundaries of a plausible spectrum in addition to or without specifying a medium value.

In order to allow comparisons with other regional and global projections, Table 6 is extended in various ways. For some regions, values for 2025 are established by interpolating the authors' projections for 2020 and 2030. For some other regions, values for 2050 are derived by determining a range around the authors' central projections or by considering additional information in the underlying regional papers for extrapolation. The extended projections are presented in Table 7.

The IAEA has been publishing the annual Energy, Electricity and Nuclear Power Estimates since 1981. These publications report on the actual status and future estimates of energy use, electricity production and nuclear power generation in all regions of the world for the near to medium term. The estimates are prepared in close collaboration and consultation with several international, regional and national organisations and international experts dealing with energy-related statistics and projections.

Table 6 Overview of nuclear capacity projections in the regional papers

	Nuclear capacity (GWe)												
	2005	*2020*			*2025*			*2030*			*2050*		
Region		*low*	*med*	*high*	*low*	*med*	*high*	*low*	*med*	*high*	*low*	*med*	*high*
West and Central Europe, Turkey[1]	135				15		135				15		270
Eastern Europe and Caucasus[2]	13					24						35	
Russia and Central Asia[3]	23		40						60			100	
West Asia, North Africa[4]	0				4		10				10		40
Sub Saharan Africa[5]	2				9	22	45				26	118	275
South-west Asia[6]	1				4	5					14	21	
South Asia[7]	4		21		31		43				190		255
South-east Asia[8]	0				8	13	15					36	
East Asia[9]	8		32	51					50	90	120		
Far East Asia[10]	66		84			89			94				
South Pacific[11]	0												
North America[12]	113				123		180						
Latin America[13]	3				5		11				15		80
Total	367												

[1]van der Zwaan's (2008) high estimates assume constant nuclear share in electricity generation.

[2]Purtov (2008) Figures 5 and 7.

[3]Chebeskov and Kagramanian (2008) text.

[4]Rogner and Abdel-Hamid (2008) text.

[5]Kenny (2008) Tables 6–9.

[6]Mumtaz et al. (2008) Tables 1 and 3.

[7]Grover (2008), 2025 and 2050 low and high values derived from Figure 3.

[8]Sudarsono and Weisser (2008) text.

[9]Li (2008) Table 9.

[10]Nagano (2008) Figures 1 and 3.

[11]Matysek and Fisher (2008) text.

[12]Hagen (2008) Table 3.

[13]Simbalista (2008): numbers for 2025 from text, estimates for 2050 derived from Table 5.

Table 7 Overview of the extended nuclear capacity projections in the regional papers

	Nuclear capacity (GWe)						
	2005	*2025*			*2050*		
Region	*ref*	*low*	*med*	*high*	*low*	*med*	*high*
West and Central Europe, Turkey	135	15	*75*	135	15		270
Eastern Europe and Caucasus	13		24		*30*	35	*40*
Russia and Central Asia	23		50		*70*	100	*130*
West Asia, North Africa	0	4	*7*	10	10		40
Sub Saharan Africa	2	9	22	45	26	118	275
South-west Asia	1	3.7	5		14	21	28
South Asia	4	31	*37*	43	190		255
South-east Asia	0	8	13	15	*24*	36	*48*
East Asia	8		41	71	120	*160*	*200*
Far East Asia	66		89		*102*	*108*	*114*
South Pacific	0		0		0	0	0
North America	113	123	*151*	180	*250*	*350*	*500*
Latin America	3	5	*8*	11	15		80
Total	367		522		866		1980

For some regions numbers in italics are interpolated from low-high projections for 2025 and extrapolated for 2050. ref – reference, med – medium.

See Table 6 and the regional papers for the original projections.

The estimates of nuclear power capacities and generation are prepared by using the bottom-up approach. Every year, nuclear power programmes and plans of the IAEA's Member States are reviewed to prepare low and high estimates of nuclear power capacity expansion for the period up to 20–25 years ahead. These two sets of estimates represent plausible ranges based on the judgement of energy experts. The low estimates are based on the number of units under construction or firmly planned, current retirement and life-extension plans, and the medium-term plans announced by governments and power utilities. The high estimates are based on upward revision of the low estimates, essentially assuming full implementation of the announced medium-term plans of nuclear power development.

Table 8 compares the most recent IAEA estimates (IAEA, 2007) with the medium-term projections in the regional papers of this SI. For some regions (especially Sub-Saharan Africa, South Asia and South-east Asia), authors of the regional papers appear to be more optimistic than the IAEA estimates. In a few other cases (especially West and Central Europe), the regional authors seem to be more cautious in assessing the 2025 prospects. Nevertheless, the global aggregate of the SI's regional medium projections sits comfortably around the mid-point of the IAEA low and high projections.

The annual reports in the Word Energy Outlook (WEO) series published by the OECD's International Energy Agency (IEA) are considered to be one of the most authoritative sources of international energy assessments and projections. The basic component of each WEO is the Reference Scenario that projects the evolution of energy demand and supply under the actual policy regime. These are complemented by alternative policy scenarios that assess the implications of changes in government policies affecting energy. Accordingly, the latest WEO 2007 Reference Scenario assumes that policies prevailing in the middle of 2007 will continue. The Alternative Policy Scenario assesses the implications of policies and measures considered by governments around the world to alleviate problems of energy security and climate change in the middle of 2007 (OECD IEA, 2007).

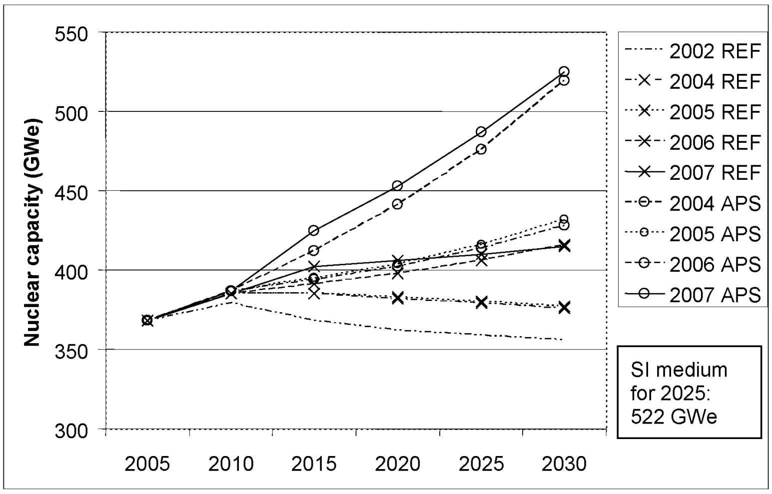
Table 8 Comparison of regional projections in this SI with the IAEA (2007) projections for 2025

	Nuclear capacity (GWe)					
		SI projections			*IAEA projections*	
	2005	*2025*			*2025*	
Region	*ref*	*low*	*medium*	*high*	*low*	*high*
West and Central Europe, Turkey	135	15	75	135	90	164
Eastern Europe and Caucasus	13		24		17	18
Russia and Central Asia	23		50		48	57
West Asia, North Africa	0	4	7	10	2	5
Sub Saharan Africa	2	9	22	45	3	5
South-west Asia	1	3.7	4.8		2	4
South Asia	4	31	37	43	17	28
South-east Asia	0	8	13	15	2	4
East Asia	8		41	71	26	39
Far East Asia	66		89		91	103
South Pacific	0		0		0	1
North America	113	123	151	180	130	149
Latin America	3	5	8	11	6	9
Total	367		521.8		433	588

ref – reference.

It is interesting to review the evolution of the WEO global nuclear energy demand projections over time (see Figure 3) and compare them to the aggregated global projection emerging from the regional papers in this SI. First, the WEO reference scenarios published up to 2005 consistently projected a decline in global nuclear capacities after 2015 while the last two outlooks (OECD IEA, 2006, 2007) project modest increases. Second, the alternative policy scenarios – initially responding to climate change concerns and in recent years also reflecting strategies to cope with drastically increased fossil fuel prices and supply security risks – project higher nuclear capacities both relative to the associated Reference scenario and over time in subsequent outlooks. The medium global projection of 522 GWe nuclear capacity for 2025 in this study (see Table 7) is about 10% higher than the latest Alternative Policy Scenario projections in WEO 2006 and 2007. This indicates that authors of our regional papers in this SI have already accounted for a modest nuclear revival in their projections due to climate protection, supply security and other reasons summarised in Table 4.

Figure 3 World nuclear energy capacities in the WEO Reference and Alternative Policy Scenarios compared to projections in this SI (GWe) for 2025



It is difficult to make long-term projections for energy sectors and technologies, particularly in times possibly involving major transformations. Yet the time scales and inertia involved in developing and deploying energy technologies require that projections take a long-term perspective. Therefore, it is worthwhile to compare the outcome of this study with the results of recent long-term studies as well.

In its interdisciplinary study on the future of nuclear power, the Massachusetts Institute of Technology (MIT, 2003) prepared mid-century electricity demand scenarios and nuclear projections. These projections involve high and low values of nuclear power generation and associated capacities for 2050. Table 9 shows the MIT projections aggregated according to the regionalisation of the present study. Although our global totals emerge from 13 independently prepared regional studies, they are surprisingly consistent with the MIT values emerging from a single projection following the same simple method for all countries. The low projections in our study result in a 10% lower aggregated global capacity than the MIT low case. In contrast, the global aggregation of the high projections in this SI is about 20% higher than the MIT high case. There are somewhat larger discrepancies for some regions and the relevant assumptions and explanations are available in the regional papers.

The Intergovernmental Panel on Climate Change (IPCC, 2000) prepared a set of global emissions scenario for GHGs on the basis of four qualitative storylines (A1: economic orientation with continued globalisation, A2: economic orientation with regional fragmentation, B1: environmental orientation with global sustainability, and B2: environmental orientation with local sustainability) and 7 variations (within the A1 scenario group variants with balanced fuel shares, high fossil shares and fast technological development induced fuel shares in the global energy mix). Research teams around the world used six global energy-economy models to quantify the storylines in terms of the major driving forces (population, economic growth, technological changes, etc.) at various degrees of geographical resolution and produced 40 scenarios of energy use and GHG emissions. The models include: the Asia Pacific Integrated Model (AIM), the Model for Energy Supply Strategy Alternatives and their General Environmental

Impact (MESSAGE), the Mini Climate Assessment Model (MiniCAM), the Integrated Model to Assess the Greenhouse Effect (IMAGE), the Multiregional Approach for Resource and Industry Allocation Model (MARIA) and the Atmospheric Stabilisation Framework model (ASF) – see IPCC (2000) for short model descriptions.

Table 9 Comparison of regional projections in this SI with the MIT (2003) projections for 2050

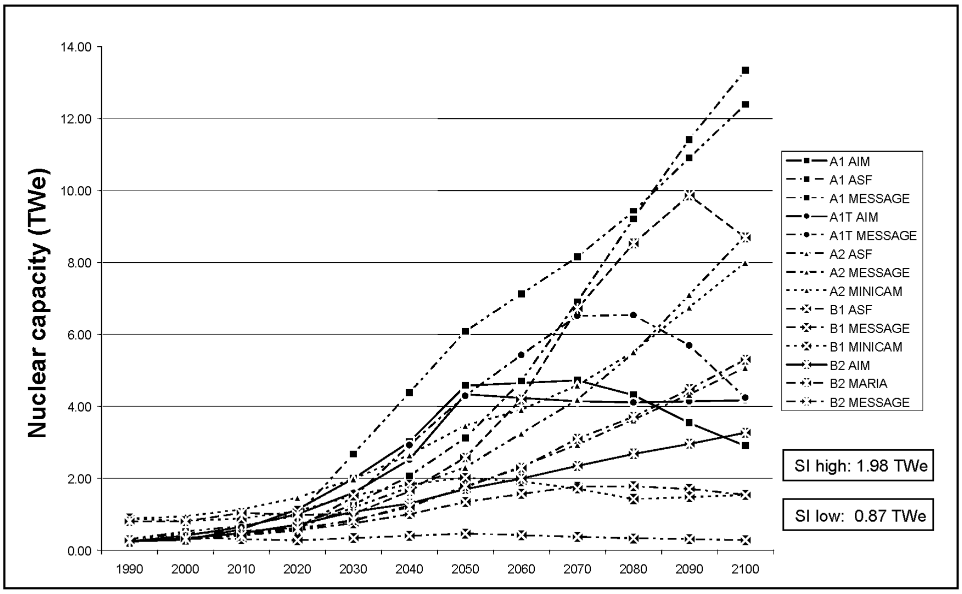
	Nuclear capacity (GWe)					
	2005	*SI 2050*			*MIT 2050*	
Region	*ref*	*low*	*medium*	*high*	*low*	*high*
West and Central Europe, Turkey	135	15		270	187	255
Eastern Europe and Caucasus	13	30	35	40	8	11
Russia and Central Asia	23	70	100	130	34	59
West Asia, North Africa	0	10		40	22	43
Sub Saharan Africa	2	26	118	275	7	15
South-west Asia	1	14	21	28	10	20
South Asia	4	190		255	87	175
South-east Asia	0	24	36	48	33	64
East Asia	8	120	160	200	103	205
Far East Asia	66	102	108	114	87	128
South Pacific	0	0	0	0	6	11
North America	113	250	350	500	333	559
Latin America	3	15		80	24	48
Total	367	866		1,980	941	1,593

ref – reference.

The IPCC scenarios depict a rather diverse set of potential futures for nuclear power through the 21st century (see Figure 4). The share of nuclear power in the global primary energy supply increases to about 20% in IMAGE in 2100 (derived number, not in Figure 4) and to 40% in the MARIA models in some scenarios while it remains around 13% in MESSAGE and below 10% in AIM in all scenarios.

It is interesting to observe that the global projections aggregated from the regional studies in this SI are in the low spectrum of the IPCC nuclear capacity paths in 2050. Only one of the 14 main IPCC scenarios (B1 with the MESSAGE model) projects lower capacity than the low projection of 866 GWe calculated from the regional papers. Results from several models under different IPCC scenarios are spread around the 2 TWe mark (the global projection aggregated from the high cases of our regional studies) but the same number of IPCC scenarios project 3–4.5 TWe nuclear capacity for 2050, around the double of the global high projection resulting from the present study. This is remarkable because the IPCC scenarios do not assume GHG mitigation beyond those in place at the time of preparing the report (before 2000) while high-nuclear cases in most regional papers in this SI explicitly allude to climate change mitigation as the main reason for larger nuclear power capacities by mid-century. The reason might be that most of the global energy models used in the IPCC scenarios use economic optimisation (e.g., least-cost energy supply) and produce larger nuclear shares and capacities than our regional authors who also consider social and political concerns and constraints in their outlooks.

Figure 4 World nuclear energy capacities in selected IPCC (2000) scenarios compared to projections in this SI (TWe) for 2050



SI high and low values indicate the range of projections for 2050.

Considering the non-traditional approach (light coordination but independent work by authors) of producing this collection of regional outlooks, the results approximate those of other projections reasonably well. Nevertheless the special value of the regional studies is not the numerical projections they present but rather the region-specific analysis of the appealing factors and negative concerns related to nuclear power. Taken together, the global mosaic is diverse but involves useful lessons for technology developers, investors and policymakers alike.

5 Conclusions

The main objective of this SI is to provide a global mosaic of the prospects for nuclear energy over the next few decades. The global picture is emerging from the entirety of regional pieces covering most countries of the world. The main conclusion is that the salient reasons for considering nuclear power in the national energy portfolios include hedging against supply security risks and high fossil energy prices in most countries, complemented by perceived future needs to reduce GHG emissions in developed countries and by the increasing realisation of the health, economic and ecological impacts of local and regional air pollution and the need to reduce the related emissions in developing countries. Concerns over nuclear power include operation safety, nuclear weapon proliferation, economic performance, nuclear waste disposal and public acceptance. Yet, the relative importance of these factors diverges widely across regions and countries.

Many factors will influence the prospects for nuclear energy: economic performance, safe deployment, political support, and others. Yet the cure to many of the above concerns will arise from advancements in nuclear science and investments in technological R&D. Technological development in nuclear power relative to other energy technologies will be the decisive element in determining whether its future in the reviewed regions and the globe as a whole will unfold along the higher or lower scenarios. The two papers by Rogner et al. (2008a, 2008b) estimate the performance targets for nuclear power in order to compete with other energy sources and technologies. Many regional papers highlight one or other technological criteria specifically relevant for introducing nuclear energy or increasing its role in the regional energy balance. One of the thematic papers (Shea and Zentner, 2008) is explicitly devoted to the security concern and technological criteria for increasing proliferation resistance.

The approach chosen to develop the regional outlooks is somewhat experimental. Although a reasonably detailed guidance and paper outline was provided to the authors, the papers are rather different, particularly in providing numerical analyses of the past and projections for the future. Nevertheless, this experimental methodology produces a diverse and interesting set of essays on the regional prospects and on selected thematic issues of nuclear power. It is hoped that, taken together, the collection will be a useful contribution to the increasing number of studies assessing the prospects for nuclear power over the coming decades.

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