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Does Europe Need a Comprehensive Energy Policy?

The nuclear meltdown in Fukushima has given renewed momentum to the anti-nuclear power movement across Europe. However, the degree of momentum varies greatly from country to country, and considering the geographically widespread consequences of a nuclear accident, it hardly appears optimal for one country to ban nuclear power while multiple nuclear power plants are still active in neighbouring countries. Even beyond the nuclear power dilemma, the economic and political externalities associated with energy policy are difficult to overstate. The contributions to this Forum look into the benefits expected from a comprehensive common energy policy for Europe and the problems which establishing such a policy would involve.

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The Future of EU Energy Policy after Fukushima

Over recent years, the European Union has progressed at increasing speed towards a common energy policy. After five decades in which EU energy policy has been confined to the narrow fields of coal and nuclear energy, deriving its authority from the treaties on the European Coal and Steel Community (ECSC) and on the European Atomic Energy Community (Euratom), the Lisbon Treaty has finally established an EU energy policy competence. Article 194 creates a legal basis for European energy policy. Energy was one of the few areas in which the EU obtained new competencies, as opposed to a clarification and consolidation. This constitutes a remarkable turnaround compared to a situation in which member states have jealously been guarding their authority over energy. Immediately before and after entry into force of the Lisbon Treaty, previously unthinkable progress towards a genuine EU energy policy, i.e. EU-level policy formulation has been made. The events in Fukushima threaten to derail this.

The Need for an EU Energy Policy

For many years, outside the remit of the ECSC and Euratom, EU policy has been limited to a series of broad horizontal (intergovernmental) policy goals such as promoting the rational use of energy and reducing Europe's oil-import dependency. Periodic attempts to extend the EU's jurisdiction in times of real or perceived threats to energy supplies remained unsuccessful. EU policies seldom went beyond a broad consensus on general objectives (e.g. in the case of energy on competitiveness, environment and external relations) and suffered from a lack of effective implementation.

Successive attempts by the European Commission and some member states, supported by the European Parliament, to introduce an energy chapter into the EC Treaty (TEC) have consistently failed due to the general resistance of member states to granting further energy competencies to the EU. Although the Maastricht Treaty introduced a new article (Article 3u), which added "measures in the field of energy as legitimate Community activities", this by no means constituted an EU competence or authority in the field of energy. A number of member states were reluctant to lose their real or perceived autonomy over energy policy due to the differing interests of producer and non-producer countries as well as the different structures of national energy sectors, best exemplified in the organisation of network energy industries.[1] For the same reason, the creation of a single energy market was originally neither part of the European Commission's 1995 White Paper on the internal market nor of the Single European Act (SEA), the treaty revision of 1986 that led to the implementation of the internal market. However, this "anomaly" was already revised in 1988 by including energy in the internal market programme.[2]

This is not to say, however, that EU energy policy did not exist altogether. In the absence of explicit competencies, the European Commission has – implicitly – been able to influ-

1 Jacques Pelkmans: Making EU Network Markets Competitive, in: Oxford Review of Economic Policy, Vol. 17, No. 3, 2007, pp. 432-456.

2 Stephen Martin, Ali El-Agraa: Energy policy and energy markets, in: Ali M. El-Agraa (ed.): The European Union, chapter 17, pp. 314-329, 8th edition, Cambridge 2007, Cambridge University Press.

ence energy policy by EU competency in such areas as the internal market (e.g. the opening of energy markets to competition, technical harmonisation, tax approximation and public procurement), competition policy and, more recently, the environment, including climate change. This allowed the EU to shape the markets for different fuels and products, notably in electricity and gas, leading to a deepening of integration in the energy sector. The completion of the internal market for energy including electricity and gas is leading to the convergence of market structures, notably regarding primary fuels and generation technologies. Liberal markets favour solutions with the lowest capital investment and the shortest returns, e.g. gas and coal plants, over more capital-intensive technologies such as nuclear. Convergence was reinforced through EU competition policy. Electricity and gas market liberalisation reduces governments' levers to influence investment decisions. Increasing cross-border trade requires cross-border regulation, thereby gradually providing for a bigger role of EU-level regulation.

In parallel, the EU saw a transition from a rather comfortable energy supply situation with a healthy diversification as regards both energy sources and geographical origin[3] to a position where domestic reserves are dwindling at the same time that government intervention in the energy industry is on the rise in precisely those countries that could potentially fill the gap.[4] Enlargement added new member states to the EU that did not enjoy the same degree of diversification and in many instances were highly dependent on Russian imports, especially natural gas.[5] In such a scenario, the EU and its member states have been examining in particular domestic policy options to move towards a more secure and sustainable supply of energy. Member states also started to realise that a more aligned external energy policy can add value to cope with this increasingly "hostile" environment.

3 Domestic and Norwegian resources enabled the EU to limit import dependence. Oil was abundantly available and oil markets were efficient and liquid. Also, some 60-80 per cent of the world's natural gas reserves are at an economically transportable distance from Europe, which also enjoys a near monopsony with Russia, home to the world's largest gas resources. Other supplies such as those from Northern Africa were also considered secure as these countries depend in many cases exclusively on oil and gas for foreign exchange revenues. Furthermore, massive investments in nuclear energy in the 1970s and 1980s allowed nuclear power to play an important role in the energy mix, with a positive effect on overall import dependence (albeit associated with other security of supply risks).

4 While many supplier countries seem unable to increase production due to a lack of investments, the fact that supplies are tightly controlled by governments in exporting countries raises the fear of "excessive" leverage by supplier countries such as Russia. Some supplier countries are hostile towards the West. Others are politically unstable. Many reserves will take years to develop due to problems of access, investments and physical conditions. A prolonged tight market has increased political tensions and risks "resource nationalism".

5 Pierre Noël: Beyond Dependence: How to deal with Russian gas, ECFR Policy Brief No. 9, London, November 2008, pp. 1-17, European Council on Foreign Relations.

On top of this, the EU and the world at large face the long-term climate change challenge. Since some 80% of all greenhouse gas emissions are energy related, the EU aims for a low-carbon and generally more sustainable energy sector. This set the stage for the integrated Climate and Energy Package, adopted by the European Council on 6 April 2009.[6] Principle elements of this package include a set of EU targets – generally referred to as "20 20 by 2020" – and accompanying policies. More specifically, the EU set itself legally binding targets to unilaterally reduce greenhouse gas emissions by 2020 by 20% compared to 1990 levels (up to 30% if other developed countries commit to comparable emissions reductions) and to increase the share of renewable energy in the EU's total energy consumption to 20%. The EU also adopted an energy efficiency goal aimed at reducing primary energy consumption by 20% by 2020 compared to projections. As this target – to date – is non-binding, there are questions as to whether it will be met. Moreover, the revised EU Emissions Trading System (ETS) has set an annual GHG reduction target of 1.74% starting in 2013.[7]

6 For a press statement on the Council's adoption of the "climate-energy legislative package" as well as links to all of its elements, see http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/misc/107136.pdf.

7 A.D. Ellerman, F. Convery, C. de Perthuis: Pricing Carbon: The European Union Emissions Trading Scheme, Cambridge 2010, Cambridge University Press.

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The fact that decisions related to the fuel mix remain subject to unanimity and therefore de facto under member state authority did not seem to matter much because markets converged, driven by market liberalisation, EU regulation and the application of competition policy. Most importantly, the Climate and Energy Package has further reduced member states' autonomy in deciding on their own energy mix. According to the National Renewable Energy Action Plans, which provide roadmaps on how each member state aims to reach its binding national renewables target set out in the Renewables Directive, renewable energy should constitute some 37% of Europe's electricity mix by 2020.[8] Furthermore, the EU ETS will make high-carbon fuels such as coal increasingly uncompetitive.

All this contributed to a change of mind towards a more integrated EU energy policy that became apparent at the 2005 informal European Summit at Hampton Court, at which European heads of state and government called on the Commission to develop a new European energy policy. The conclusions of Hampton Court were later laid out in the Green Paper of March 2006[9] and further developed in the First Strategic Energy Review.[10]

This previously unthinkable rapprochement towards a genuine EU energy policy has been accelerated by entry into force of the Lisbon Treaty on 1 December 2009. It elevates energy into an area of shared competence between the Union and the member states (Article 4 TFEU). At the same time Article 194 TFEU mandates overall EU energy policy to focus on the establishment and functioning of the internal market, on securing EU energy supplies, on energy efficiency and renewables and on the interconnection of energy networks. The same article includes a reference to solidarity which is repeated in Article 122 TFEU, referring to solidarity between member states in the case of severe difficulties in the supply of energy. Being a shared competence, energy policy has become subject to majority voting with an enhanced role of the European Parliament as it falls under the "ordinary" procedure. Member states can only regulate energy issues when the Union has not exercised its competence.

The stage has been set for the gradual yet steady development of an EU energy policy, including an external energy policy. Further and unexpected impetus has been provided by the economic crisis. In response to the global economic crisis starting 2008/2009, the EU decided on a European Economic Recovery Plan (EERP), which foresaw the spending of some €4 billion on interconnectors (e.g. electricity and gas), off-shore wind projects and carbon capture and storage. The EERP was thus aimed at strengthening grids and addressing security of supply concerns that became especially apparent during the latest Russia-Ukraine gas crisis in 2009.[11] The EU has been able for the first time to spend a significant amount on energy infrastructures beyond the Trans-European Network, and this is seen as a possible precursor for more to come. At the same time, it can be seen as a first step in making solidarity operational beyond the "mantra" of market-based solidarity, i.e. the free flow of energy in a liberalised, integrated and interconnected European energy market.

Another step forward has been the Security of Gas Supply Regulation[12], which requires member states to draw up strategies to assess gas supply risks and measures to address them. Only residual risks should then be dealt with by the EU. This can be seen as a step towards addressing the risk of "moral hazard"[13], which is a prerequisite for active EU solidarity. In fact, the Gas Regulation could serve as a model for assessments of other potential security of supply risks including, for example, oil supplies including refining, investment adequacy for different fuels, risks stemming from possible accidents, environmental pressures and energy price volatility.

Nevertheless, some continue to argue for a more centralised EU energy policy, moving towards a European Energy Community built upon consensus.[14] Since such a Community cannot be achieved immediately, the proposal – in good EU tradition – builds upon the "Europeanisation" of a limited number of areas where a common approach could possibly be achieved. Such areas include i) strengthening cooperation with respect to energy networks, ii) a common energy fund for financing new technologies in renewable energies

8 European Commission: Renewable Energy: Progressing towards the 2020 Target, COM(2011) 31, 31 January 2011.

9 European Commission: A European Strategy for Sustainable, Competitive and Secure Energy, Green Paper, COM(2006) 105, 8 March 2006.

10 European Commission: An energy policy for Europe, COM(2007) 1, 10 January 2007.

11 S. Pirani, J. Stern, K. Yafimava: The Russo-Ukrainian gas dispute of January 2009: a comprehensive assessment, Oxford Institute for Energy Studies Working Paper, Oxford 2009.

12 The adopted Regulation, apart from giving a stronger role to the EU in coordinating member states' responses to supply disruptions and declaring emergencies, requires member states to draw up preventive action and emergency plans for the case of disruption. It also introduces supply and infrastructure standards to ensure that normal supplies can be maintained during the coldest winters and provides for the introduction of reverse flow technologies in all interconnections between member states. Explicitly, the Regulation includes measures to ensure that security of supply would not be used as a loophole to distort the internal market, and to ensure that companies can sell gas where it is needed.

13 "Moral hazard" occurs when a member state is (partly) insulated from risks because of EU guarantees and therefore takes bigger security of supply risks than it would if it had to bear the full effects of a supply disruption itself.

14 Sami Andoura, Leigh Hancher, Marc van der Woude: Towards a European Energy Community: A Policy Proposal, Policy Proposal by Jacques Delors, 2010, Notre Europe.

and networks and iii) the establishment of a Gas Purchasing Group. It is envisaged that only a number of member states would initially participate with others being able to join later. This nucleus of tasks and member states would gradually develop over time into a fully-fledged Energy Community encompassing all member states and all relevant tasks (of a cross-border nature) once the necessary consensus is found.

Will Fukushima Derail EU Energy Policy?

As long as a general consensus on the direction prevailed, progress towards an EU energy policy has been impressive and seemed unstoppable. Numerous new initiatives have been launched by the European Commission including proposals for an energy strategy for the period until 2020, infrastructure development and energy efficiency, to name but a few.[15] The European Council, on 4 February 2011, finally made a first step to align member states' and EU energy policies when it "invited" member states to "inform" the European Commission of "all their new and existing bilateral energy agreements with third countries".[16] While this is not yet a compatibility test of member states' agreements with EU objectives, it is a first step in this direction.

As soon as the tragic events of Fukushima unfolded, the apparent consensus disappeared and the shortcomings of the current EU energy policy framework became evident. National preferences quickly trumped EU considerations. Driven by rapidly growing public opposition to nuclear power, which threatened to jeopardise the survival of a regional government, the German government quickly announced a three-month moratorium on the extension of the life span of its nuclear reactors decided barely six months earlier. The government also decided to test the safety of all its nuclear power plants and to – temporarily – shut down (or not restart) eight of Germany's oldest plants that were considered potentially unsafe and that produce a net output of 8.4 gigawatts. This was done without informing, let alone consulting with, its neighbours. In fact, the Executive Director of the IEA recently recommended that Germany seek a European solution to its nuclear energy policy to avoid putting the security and sustainability of European energy supplies in danger.[17] However, Germany was not alone in its unsynchronised decision to revise its nuclear policy; many other EU member states similarly decided on audits of their nuclear installations and programmes in a rather uncoordinated fashion before the voluntary EU "stress tests" were announced after an emergency meeting of the European Council on 21 March 2011.[18]

Such abrupt policy changes impact neighbouring countries and markets, risking short-term disruptions that markets will only address in the medium term. Phasing out nuclear plants in Germany or elsewhere will trigger investment in alternative generation, be it in renewables, thermal (gas or coal) or even new nuclear in those member states where nuclear energy is politically acceptable. As regards the latter it should be noted, however, that economics speaks against large-scale additions to nuclear capacity in Europe. New projects have been characterised by exploding investment costs coupled with largely unpredictable future revenues in increasingly liberalised electricity markets. Unless carbon prices under the EU ETS increase significantly – something not expected until 2020 – the profitability of new nuclear power plants will not decisively increase compared to more carbon intensive energy sources. Increasing public opposition in the wake of Fukushima would certainly increase the political risk related to nuclear and thereby also have a negative effect on the economics.

Potentially far more divisive and disruptive is the issue of nuclear safety. Irrespective of current safety rules, there will be additional safety measures and they will reduce the risk of serious accidents (albeit at increasing costs). However, as with other technologies, this risk can never be reduced to zero. Fukushima has shown that accidents can go beyond the worst-case scenarios imagined by power companies and governments, and thus beyond the safety measures of nuclear power plants. And although there is a very low probability, such accidents can have devastating consequences. If member states decide to live with this residual risk, then they must address the potential cross-border implications of radiation. In fact, since any large-scale nuclear accident in Europe would have European-wide consequences, there needs to be a consistent and binding approach to the highest nuclear safety standards across all EU member states on the European level. This is an EU issue in line with the subsidiarity principle as laid out in Article 5(3) TEU.

The recent saga about EU stress tests is a case study of how not to do it. A few days after the accident in Fukushima, EU Energy Commissioner Oettinger proposed that all nuclear power plants be submitted to a review on the basis of comprehensive and transparent risk and safety assessments (i.e.

15 European Commission: Energy 2020 – A strategy for competitive, sustainable and secure energy, COM(2010) 639 of 10 November 2010; European Commission: Energy infrastructure priorities for 2020 and beyond, COM(2010) 677 of 17 November 2010; European Commission: Energy Efficiency Plan 2011, COM(2011) 109 of 8 March 2011.

16 European Council, 4 February 2011, Conclusions, EUCO 2/1/11 REV 1, CO EUR 2 CONCL 1, 8 March 2011.

17 Financial Times Deutschland: Energieagentur fürchtet Atomausstieg, 23 May 2011.

18 Council of the European Union: Press Release, Extraordinary Council meeting, Transport, Telecommunications and Energy, Energy Items, PRESSE 72, PR CO 19, 21 March 2011.

"stress tests"). This would have been a genuine European response. However, since EU competences are very limited as regards nuclear safety issues, member states could only agree on the least common denominator in the form of voluntary tests based on criteria that are lower than those applied by many national regulators, possibly even excluding man-made events such as severe human error, sabotage or malevolent attack. Under the Euratom Treaty, sanctions are only possible with regard to the safety of nuclear fuel (i.e. to prevent proliferation) and not to safety standards of nuclear power plants. Similarly, there is no deadline for adopting the stress tests and there is no guarantee that negative results will have any consequences since decisions on individual installations remain a national responsibility.

In the longer term, however, Fukushima may result in a chance to increase EU competence and raise standards as regards nuclear safety. This could start with a revision of the Euratom Treaty with a stronger focus on binding Europe-wide safety standards, but also on eliminating legal inconsistencies with the new legislative structure of the EU. This could, for example, lead to the European Parliament being given co-decision powers on related matters. In addition, there may now be mounting pressure to raise safety standards as laid out in the Nuclear Safety Directive, and at least to make the IAEA Fundamental Safety Principles binding at the European level (and in neighbouring countries). In the longer term, the establishment of a European regulatory body responsible for setting, implementing and enforcing EU-wide safety standards may even be considered.

If European energy policy is to have a meaning in the future, then it will need to address the risk of the cross-border externality of radioactive fallout from a nuclear reactor, including procedures for measures to be taken in the case of an accident and for compensation across borders. Otherwise, clauses on solidarity will sound empty and hinder EU energy policy development. This is the minimum that the EU must achieve if there is no consensus on nuclear energy in the EU. Whether this will "save" nuclear energy, i.e. lead to new investments, is another matter. This will be discussed in other contributions to this Forum.

Richard S.J. Tol

The Impact of EU Enviromental Policy on the Energy Sector

EU energy policy is by consensus, that is, virtually non-existent. As of 2014, unanimity will be replaced by qualified majority voting, and we may expect to see the emergence of an EU energy policy. However, in the name of environmental policy, the EU has exerted considerable influence over the energy sector. In this paper, some of the issues will be reviewed.

EU environmental policy has always been by qualified majority, at least officially. In practice, EU environmental policy is driven by the political agenda of a small group of countries (Austria, Denmark, Germany, the Netherlands, Sweden and the United Kingdom). Other member states have accepted this in return for regional and agricultural subsidies. Environmental policy increasingly intrudes into other policy areas. As energy is a large source of a variety of emissions into the atmosphere, environmental policy shapes energy policy.

Acidification

This has been going on for a long time, but it has not always been obvious. Acid rain has long disappeared from the media and political agenda. The Large Combustion Plants Directive regulates sulphur dioxide, nitrogen oxides and dust emissions from power plants. This is primarily to reduce acidification. The Directive puts a cap on the total amount emitted per plant. There are two ways to achieve this. First, there is end-of-pipe technology that "scrubs" the pollutants from the flue gas. Second, the plant can be closed. As retrofitting a power plant with scrubbers is expensive and as scrubbing uses energy, the second option may be the best. This is particularly the case for older coal plants, which already have difficulty competing with newer plants and would have only a short period to earn back the investment in flue gas desulfurisation.

The Large Combustion Plants Directive thus effectively closes older coal plants. That may be a sensible thing to do for environmental reasons, but it has ramifications for energy policy. The impact is perhaps strongest in the UK. The idiosyncrasies of privatisation and deregulation in power generation mean that capital investment has not been sufficiently incentivised. Power companies have been sweating their assets, and have not invested enough in new power plants. The peculiarities of planning regulation mean that it is difficult to build new power plants in England and Wales, even if one wanted to. The UK is thus heading for a power shortage, with rolling brown-outs a real possibility by the end of the decade. This can still be avoided through a crash programme of investments in gas-fired power plants. Although domestic energy policy has played a major role in this, EU environmental policy is a key ingredient. Keeping the coal-fired power plants open for a few more years would allow the UK to carefully consider and plan the upcoming major investment in new power generators.

The Climate and Energy Package

The impact of the EU climate and energy package will be more substantial than the regulation of air pollutants. The climate and energy package has a number of targets. In 2020, greenhouse gas emissions should be 20% below what they were in 1990. Renewables are to provide 20% of total final energy use (and 10% of transport fuel use). And primary energy consumption is to be 20% below what it otherwise would have been in 2020, due to increased energy efficiency. Whereas the last target is aspirational (at least for now), the first two targets are legally binding.

Electricity

EU climate policy has far-reaching implications for power generation and the regulation of electricity markets.

The EU Emissions Trading System (ETS) for carbon dioxide permits puts a price on emissions from power generation and selected energy-intensive industries. This promotes energy efficiency improvements, favours renewable and nuclear power over fossil fuels, and furthers natural gas at the expense of coal. It has created new activities in energy finance and consulting. Because initially emission permits were grandparented, there was an implicit transfer of wealth from society to companies. Permit holdings are now a substantial part of the balance sheet of power companies and have been used to finance expansion and diversification. Over the course of the decade, an increasing share of emission permits will be auctioned rather than grandparented. Wealth will be transferred from companies to the European Commission[1], putting pressure on the balance sheet of companies at a time when new investment is needed.

Previously, power generation had two main aims: reliable and affordable electricity. Now it has three: reliable, affordable and clean electricity. Reliability and affordability are at odds with one another. Reliability is best achieved by expensive redundancy. Clean electricity conflicts with both other aims. Carbon dioxide emission reduction raises the price of electricity. The market for coal is less prone to disruption than the market for gas, while solar and wind power are intermittent and volatile. As clean electricity has the force of EU legislation behind it, member states are forced to pursue it without sufficient regard for the reliability and affordability of electricity.

The rapid expansion of renewable energy is another major change in the energy sector brought about by EU environmental policy. Because renewable technologies for electricity are more mature than renewables for heating or transport, power generation will be the main area for the expansion of renewables. Wind and solar power will account for the lion's share of new renewable electricity. Wind and solar power are non-dispatchable, that is, the operator has little control over the power supplied to the network. This means that a range of auxiliary services needs to be provided to guarantee capacity, regulate frequency and improve flexibility. Capacity is well-regulated already; the existing arrangements only need to be scaled up. Frequency and flexibility, on the other hand, used to be of little concern to regulators. The provision of sufficient capacity to meet peak demand is a public good in the power system. Likewise, the provision of flexible capacity to offset rapid changes in renewable supply is a public good. These public goods can be provided by a levy on all power generators, with the revenue going to the purchase of (flexible) capacity. Deviant frequency is an externality that could be taxed. Alternatively, frequency controllers could be treated as a public good. In any case, electricity regulators will need to introduce new regulation.

Increased interconnection is one way to accommodate wind and solar power as the law of large numbers alleviates their volatility. Interconnection also helps to solve another problem, namely that the best supplies of wind (at the Atlantic seaboard and at sea) and solar energy (in Southern Europe and North Africa) are far from the main centres of electricity demand. There is an infrastructure component to interconnection but also a regulatory one. There is no physical difference between transmission and interconnection, but whereas transmission starts and ends in the same jurisdiction, interconnection starts in one and ends in another. There is no fundamental problem with trade between jurisdictions, but it does increase transaction costs and regulatory risks, particularly in a market as tightly regulated as electricity. In an attempt to stimulate interconnection and thus pave the way for renewables, the European Commission got involved in the harmonisation of power market regulation. Although this may be desirable in the long term, at the moment it is a case of the interconnection tail wagging the domestic power markets dog.

Moreover, the intervention of the European Commission has increased regulatory uncertainty. A new regulator has entered the field. The new regulator is without a track record

1 The first structural and substantial revenue stream directly to the European Union.

and without a network and therefore particularly unpredictable.

Regulatory certainty is key in power generation, and even more so in renewables. Power generation is heavily regulated because there are common goods (security of supply, network stability), natural monopolies (transmission and distribution networks) and externalities (accidents, emissions). The capital stock is long-lived. The ability to earn a return on an investment therefore depends on the investor's skill in predicting, or influencing, future regulations. Whereas fossil electricity competes on its own merit, the market share of renewables is solely by regulatory fiat. Moreover, the cost of capital is more important to renewables than to fossil fuels.

Therefore, by increasing regulatory uncertainty, the European Commission may well have reduced the incentive to invest in the electricity sector – exactly the opposite of what they sought to achieve.

Demand-side management is another option to manage the increased volatility of electricity supply. Traditionally, electricity systems have sought to meet demand, increasing and decreasing supply as needed. Demand-side management seeks to reduce electricity demand or shift it to times that better suit supply. There are three elements to this. First, consumers can relinquish part of the control over their energy demand to the energy supplier. This is not uncommon for refridgerated warehouses, but interruptable supply contracts have a limited appeal only. Second, consumers can be provided with the necessary information to better manage their electricity use. Third, the provider can use price signals to change customers' behaviour.

Demand-side management requires smart meters, devices that collect information and communicate in real time. Smart meters have been around for a long time, and are now ready for mass deployment to every household. This has major implications. The purpose of smart meters is to enable demand-side management, which helps with the integration of volatile renewables. However, smart meters will also teach utilities about their customers. At the moment, utilities know remarkably little about households: monthly electricity use, address and payment history. With smart meters, utilities will know that you are in the habit of turning on the bathroom light at 3 a.m. In other industries, the ability to profile clients has always been followed by market segmentation and attempts at exclusion. It may well be that certain types of household are more profitable than others. New regulation may need to be introduced to prevent exclusion from the electricity retail market.

Smart meters also allow smart appliances, which use the information from the smart meter to optimise their operation. Fridges, for instance, may be slightly warmer when electricity is expensive, and the battery of an all-electric vehicle may postpone recharging. It may even discharge to the net if the price is high enough, because smart meters also allow microgeneration[2] and microstorage.[3]

Smart meters thus turn hitherto passive consumers into active market participants. If properly incentivised, active consumers should dampen price volatility by reducing demand when supply is scarce. Chances are, it will take some experimentation before proper incentives are in place.

These are uncertain times for power companies. Power generation is capital-intensive, so uncertainty matters a lot. What is more, wind and solar power are even more capital-intensive than coal- and gas-fired power. If we add the fact that European banks will need to be (re)capitalised and that governments will need to rebuild their balance sheets, then the prospects of meeting the targets in the energy and climate package do not look good.

Transport

The transport sector is a major user of energy, particularly liquid fuels. Transport policy is by and large the domain of national policy, although the European Union has been a major sponsor of transport infrastructure in accession countries and disadvantaged areas. Air pollution regulation has a large multilateral component through the UN Economic Commission for Europe. The climate and energy package will increase EU involvement in transport policy. As noted above, 10% of transport fuels are supposed to be renewable by 2020.

Furthermore, carbon-efficiency standards (falling from 130 g CO_2/km today to 95 g CO_2/km in 2020) have been imposed on the average fleet of car manufacturers.[4] As the regulation is for the fleet, averaged by sales, the impact on emissions is more difficult to predict. Car use, rather than ownership, determines emissions; and people who drive a lot tend to own (or lease) heavier and larger cars. Moreover, the sanction for violations is a fine that is modest relative to the price of a premium car. Manufacturers may choose to pay the fine and pass it on to status-conscious consumers. Overall, the standard is likely to reduce fuel use in transport, and

2 Microgeneration is electricity generation in the house (e.g. solar panels), with excess power delivered to the net.

3 Microstorage is power storage in the house, taking power from the net when the price is low and discharging to the net when the price is high. Microstorage is non-existent at present, but this may change if there is a large supply of second-hand batteries from all-electric and hybrid vehicles.

4 Manufacturers are distinguished by operations rather than ownership.

particularly that of carbon-inefficient petrol. This will mean a reduction in the growth of fuel demand and a shift in its composition, but the impact on the energy sector will not be profound.

This may not be the case for the renewables target. As all-electric vehicles only serve a small niche market, and as fuel cell and hydrogen vehicles are not yet ready for mass deployment, the renewables target will probably be met by blending bioethanol with petrol and biodiesel with diesel. This is technically straightforward. The main question is whether enough biofuels can be sourced, and at what price. The USA is ahead of Europe in this regard and the diversion of maize from food and feed to fuel has caused a sharp rise in food prices around the world. This could happen again if the EU followed through on its plans.[5]

The medium-term impact on the transport energy sector is a further distortion of the market by government policy, and a sizeable investment in a biofuel transport and processing infrastructure that would become obsolete as soon as the regulation changes, since biofuels cannot compete on the open market.

The long-term impact may be more profound. First-generation bioenergy[6] is rather clumsy. It is expensive, it competes with food, and the net energy yield is low (or even negative). Therefore, a considerable effort is being made to develop second-generation bioenergy[7] and to research third-generation bioenergy.[8] Whereas progress in second-generation bioenergy has been slow, third-generation bioenergy is causing lots of excitement in laboratories around the world.

If it is possible to upscale and commercialise some of the new discoveries, then there may be a revolution in energy supply. Exploration, exploitation, transport and processing of fuels would be transformed, and powerful players in those markets would be wiped out. Although some people speak excitedly of a "Google of energy" or a "Facebook of fuel", transport fuels would still be produced in large volumes, so that major investments would be needed in production and transport. The revolution, if there were one, would unfold over decades.

Households and Small Businesses

Space heating is another major source of energy demand. The climate and energy package does not specifically target this. However, there is a cap on greenhouse gas emissions in 2020 which cannot be met without affecting space heating. Conventional wisdom has it that a lot of energy is wasted. Energy efficiency improvements can thus reduce emissions with relatively little effort and at a relatively minor cost. A number of countries have sizeable programmes for energy efficiency, but there has been little evaluation of their costs and efficacy.

Renewable energy for both heating and electricity (see above) is also stimulated in a number of member states through a variety of taxes and subsidies – and even, in at least one case (Ireland), through both a tax and a subsidy. The European Commission has left it to the member states to meet the non-ETS part of their target. There is the possibility of bilateral trade in non-ETS emission allowances between member states, but the implementation of greenhouse gas emission reduction policy is a strictly domestic matter. As these targets mainly concern households and small businesses, domestic implementation is in line with the subsidiarity principle.

However, different member states go about reducing non-ETS emissions in very different ways. This implies new opportunities for direct importation, a distortion of cross-border service trade, and maybe even international migration in border regions. These effects could be large locally but are probably small nationally. There are no structural implications for the energy sector.

Conclusions

This article has reviewed the implications of EU environmental policy, and particularly climate policy, for the energy sector in Europe. Power generation is affected most, followed by transport and residential energy use. In electricity, the implications of climate policy go far beyond energy efficiency improvements and supply switching. More and new regulation is required to cope with the increased volatility of supply and demand, and the EU is stepping in as a regulator. At the same time, major new capital investments will need to be made. This underlines the ambition of EU climate policy. It also calls for an effective EU energy policy to counterbalance the current focus on clean energy; reliable and affordable energy are great goods too.

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5 This is not certain. Biofuels are controversial. Imported biofuels from Brazil and Southeast Asia could well run into opposition from farmers (who tend to oppose international trade) and environmentalists (who would be concerned about deforestation), while EU-grown biofuels would be very expensive and save little energy.

6 First-generation bioenergy uses existing plants and variants of ancient technologies. Examples are the burning of wood, the pressing of seeds for oil, and the making of charcoal.

7 Second-generation bioenergy uses existing plants and new technologies. Examples include gasification and cellulosic conversion of biomass.

8 Third-generation bioenergy uses new plants. That may involve breeding and genetic modification, but also plants (e.g. algae) that have hitherto been ignored.

Michel Berthélemy and François Lévêque

Harmonising Nuclear Safety Regulation in the EU: Which Priority?

Nuclear power presents the risk of severe accidents which can potentially lead to very high costs to society and the environment. In that respect, the Fukushima accident has reminded us that a nuclear catastrophe can even occur in a country with an advanced nuclear industry and has led to renewed scrutiny of nuclear safety regulation in Europe. The European Union, with its 143 nuclear power plants (NPPs), is one of the most nuclearised regions in the world, with about one-third of the world's nuclear capacity. In addition, European NPPs are spread over a large number of countries in a relatively small geographical area. As a consequence, transborder damage from severe nuclear accidents is potentially a major issue for the EU.

The 1957 Euratom Treaty and European Court of Justice (ECJ) case law[1] recognise the EU competency for liability rules and nuclear safety standards, respectively. Despite this legal basis for EU intervention in these two policy areas and the fact that the Euratom Treaty is often described as one of the "three pillars" of the EU, the current framework can be pictured as a patchwork of national laws with limited efforts to harmonise nuclear safety standards and no legislative action in the field of nuclear liability rules.

In this paper, we propose to summarise the current legal and institutional frameworks regulating nuclear safety standards and liability rules in the EU and explore their economic consequences.

The Economics of Nuclear Safety in a Nutshell

Nuclear safety is characterised both by ex ante (i.e. standards) and ex post (i.e. liability) regulation. Nuclear safety standards are based on the concept of "defence in depth", which encompasses the actions and systems in place to prevent the risks of a nuclear core failure and the release of nuclear materials in the atmosphere and water. While some risk classes – such as terrorist attacks – are difficult to be conceived of in a probabilistic framework and follow a deterministic approach, nuclear safety standards result from probabilistic risk assessments of nuclear core damage. They are set regardless of the expected cost of a nuclear accident. By contrast, liability rules apply ex post. They govern the allocation of financial responsibilities in the case of a nuclear accident and the compensation to victims. They can also require the operator to have liability insurance available up to a specific amount. In that case, liability insurance will vary depending on the expected damage that an NPP can cause.

From an economic point of view, the socially optimal level of care occurs when the marginal cost of care (i.e. the safety efforts and investments made by the operator) equals the marginal benefit (i.e. the marginal reduction in the expected cost of a nuclear accident). The economic literature[2] recognises that the combination of these two instruments can be necessary to achieve an efficient level of safety. On the one hand, when the cost of a nuclear accident differs among NPPs, the safety standard is inefficient because it does not take into account the heterogeneity in nuclear damage; unlimited liability is then superior to internalise the expected cost of a nuclear accident. On the other hand, unlimited liability is ineffective when the expected cost of damages exceeds the operator assets and standards are therefore necessary to enforce the efficient level of care. In practice, priority is given to ex ante regulation as the cost of a severe nuclear accident will both far exceed the assets of any nuclear operator and is difficult to estimate by insurers.[3]

The right balance between national and supranational nuclear standards must also be found. As seen in Chernobyl and Fukushima, most nuclear damage occurs at the local level and impacts the local population, i.e. the inhabitants in a 20-50 km radius. The local population also gets a share of the benefits through employment and taxes. It is therefore economically recommended that nuclear safety regulation take into account the way local inhabitants balance the expected costs and benefits of a nuclear power plant and its safety improvements. Within the EU, these preferences are very heterogeneous. The variation of local risk aversion across the EU is illustrated by opinion polls. According to Eurobarometer, on average 37% of the EU public are in fa-

1 European Court of Justice: Judgment of the Court of 10 December 2002 – Commission of the European Communities v Council of the European Union, Case C-29/99, European Court Reports, 2002.

2 S. Shavel: A model of the optimal use of liability and safety regulation, in: RAND Journal of Economics, Vol. 15, No. 2, 1992, pp. 271-280; M. Trebilock, R. Winter: The economics of nuclear accident law, in: International Review of Law and Economics, Vol. 17, 1997, pp. 215-243.

3 This is because of the complex nature of nuclear radiation's impacts on the environment and human health and because of the (fortunately) too limited historical number of severe accidents on which actuarial calculus can be based.

vour of nuclear energy, but support runs as high as 68% in Hungary and as low as 8% in Austria.[4]

However, significant damage can also affect distant zones owing to the dispersion of radioactive elements by aerial and water currents. Similarly, some of the benefits of nuclear power generation are enjoyed at a large distance from the power plant. To cope with these long-distance external effects[5], the preferences of people living outside the local zones of NPPs also have to be taken into account by nuclear safety regulation.

To simplify the discussion for the EU, the local vs. global dichotomy for the external effects could be assimilated to a national vs. European distinction. The majority of EU member states are small countries, and many NPPs are located close to national borders. For instance, trans-border damages are potentially an important issue for the EU as about 25% of the 143 NPPs are located within a 30 km radius of another member state (and 40% are within a 100 km radius).

To sum up, from an economic perspective there is no reason to impose a "one size fits all" level of nuclear safety. Because of local preferences, especially regarding risks, it is economically rational for identical power plants in two different areas to be regulated differently (e.g. shutting one down completely and extending the life of the other conditioned on safety improvements). To put it another way, it is not irrational that in Europe a less safe NPP could have its life extended whereas a safer one is shut down. Conversely, due to potential trans-border damage, it must be possible to shut down an NPP even if the local population would rather not close it. Neither the national nor the supranational level can unilaterally impose its safety decision upon the other. A mix between national and international standards is required, even within the EU.

What is the right mix between ex ante and ex post regulation and between state and EU-level regulation? Our aim is not to provide a definite normative answer to these difficult questions. We only seek to provide some factual and analytical elements to facilitate the discussion.

Nuclear Safety Standards in the EU

Traditionally, member states have been divided on the issue of common nuclear safety standards, which have been left in the hands of national safety authorities. At the same time, the 2002 ECJ case law 29/99 recognises that the Commission shares competences with member states in the field of nuclear safety, and with the perspective gained via the inclusion of nuclearised states from Eastern Europe in the EU enlargement, the European Commission has initiated a series of proposals to harmonise nuclear safety rules in Europe since the 2002 nuclear package. This complex and heavily debated process eventually led to the 2009/71/Euratom directive (hereafter the 2009 directive) "establishing a Community framework for the nuclear safety of nuclear installations".

Beyond the political opposition surrounding the negotiation of this directive, the European Nuclear Safety Regulators Group[6] (ENSREG) has analysed the pros and cons of establishing detailed and binding nuclear safety standards at the EU level. The ENSREG is an expert body set up to advise the Commission on nuclear safety issues and is composed of the heads of national safety authorities from the 27 EU member states. As ENSREG argues, European common nuclear safety standards would strengthen the independence of national regulators, provide the possibility for the EU to take the international lead on nuclear safety, improve dialogue with the industry at the EU level and make communication about safety more transparent. Conversely, because of differences in safety cultures and approaches, agreeing on common rules would be costly in terms of time and resources, would create problems of transposition and interpretation into national laws, would monopolise the resources of national regulators and could lead to decisions based on the least common denominator with respect to safety standards for existing reactors.

More generally, the political divisions between the proponents and opponents of nuclear power make it likely that the former may perceive EU intervention in the field of nuclear safety as a threat of legal proceedings in front of the ECJ by member states opposed to nuclear power.

While the 2009 directive must still be transposed into national laws[7], legal scholars argue that this one is substantially

4 House of Lords European Committee: 37th Report, 2006, http://www.publications.parliament.uk/pa/ld200506/ldselect/ldeucom/211/21105.htm#a12. Moreover, a more recent Eurobarometer poll (March 2011) indicates that on average 41% of EU27 citizens agree with the proposition that "the benefits of nuclear as an energy source outweigh its risks". This figure is 59% in the Czech Republic and 11% in Cyprus. See: http://ec.europa.eu/energy/nuclear/safety/doc/2010_eurobarometer_safety.pdf.

5 Note that the image and the future of the nuclear power generation industry as a whole are affected by any single catastrophe. Safety standards set by collective organisations such as Institute of Nuclear Power Operations in the USA or the World Association of Nuclear Operators attempt to mitigate this negative long-distance external economic effect of severe nuclear accidents.

6 ENSREG: Discussion document on consequences of EU instruments in the field of nuclear safety, final report, 31 March 2009, http://circa.europa.eu/Public/irc/tren/nuclear_safety_and_waste/library?l=/general_archive/public/p2009-08_instrumentspdf_2/_EN_1.0_&a=d.

7 Member states have until June 2011 to transpose directive 2009/71/Euratom into national laws.

watered down compared to the initial proposals.[8] The initial proposals created legally binding nuclear safety standards with monitoring mechanisms through the creation of an EU regulatory committee chaired by the Commission. The current directive is essentially devoted to the requirement that member states have national frameworks for nuclear safety with independent safety authorities and that they report to the Commission through a peer-review process as well as transparency platforms. In that respect, the 2009 directive is partly based on the International Atomic Energy Agency's (IAEA) "Fundamental Safety Principals" and makes these voluntary standards binding for EU member states. Moreover, the importance given to the independence of nuclear safety authorities can be considered a significant provision of the directive[9], as nuclear safety authorities face inherent risks of government pressure to ease or trigger nuclear safety standards. On the other hand, no clear definition of EU nuclear safety standards was made; this task falls to ENSREG in accordance with the mandate given to it by the Commission.[10]

In parallel to ENSREG and the EU framework, the Western European Nuclear Regulators' Association (WENRA) acts as a discussion forum to develop a common approach to nuclear safety in Europe. WENRA is a network of 17 European nuclear regulators and was created in 1999 to assess nuclear safety standards in accession countries to the EU. The WENRA members are essentially the same as those of ENSREG. However, membership is not bound to the EU borders and only includes countries with nuclear reactors. While WENRA does not have a formal mandate within the EU, it has contributed to the improvement of nuclear safety in Europe in two different areas:

- Firstly, WENRA expertise was used to provide an independent assessment of the national frameworks for nuclear safety in Eastern European accession countries. Based on its recommendations, the closure of eight NPPs in three countries was made a necessary condition for them to join the EU.[11]

- Secondly, following the Fukushima accident, WENRA expertise has also been requested by the Council to develop a common stress test of the safety margins and emergency preparedness of European NPPs in light of the events that led to the Fukushima accident.

These two WENRA contributions to a common approach for nuclear safety highlight the fact that national regulators can cooperate on a voluntary basis to promote nuclear safety standards in Europe beyond the provisions of the 2009 directive. In that respect, this framework reflects a balance between the national and supranational dimensions of nuclear safety as mentioned in the first section. Moreover, it can be argued that WENRA may be more efficient than ENSREG in making decisions to further enhance nuclear safety; at the time of writing this paper, the recent failure of ENSREG to agree on the WENRA proposal for EU stress tests shows that the political divisions between proponents and opponents of nuclear energy within the EU can hinder the efforts to agree on nuclear safety standards in Europe[12] and that achieving more harmonisation of nuclear safety standards through the EU institutions – beyond the provisions of the 2009 directive – would be a difficult task.

Liability Rules in the EU

Unlike ex ante nuclear safety regulation, the European institutions have not intervened in the field of nuclear liability rules[13], which are regulated by international conventions and national laws. First and foremost, it should be noted that the Euratom Treaty clearly states that nuclear risks should be covered by insurance contracts by member states and that both the Council and the Commission should issue directives in this field[14] and take action if a member state fails to cover these risks.[15] Despite this clear provision in the Euratom Treaty, the EU has never issued a directive or a regulation in this field; even a directive it issued for liabilities from environmental damage excluded nuclear damage from its scope.[16]

8 A. Staničː EU Law on Nuclear Safety, in: Journal of Energy and Natural Resources Law, Vol. 28, No.1, 2010, pp. 145-158; M. Sousa Ferro: Directive 2009/71/Euratom: the losing battle against discrimination and protection of sovereignty, in: International Journal of Nuclear Law, Vol. 2, No. 4, 2009, pp. 295-312.

9 For instance, the French nuclear safety authority (ASN) only became fully independent from the government in 2007.

10 Decision 2007/530/Euratom on "establishing the European High Level Group on Nuclear Safety and Waste Management".

11 Namely, NPPs in Lithuania, Bulgaria and Slovakia: Bohunice 1 and 2, Kozloduy 1 to 4 and Ignalina 1 and 2.

12 Euractiv: EU countries divided over nuclear stress tests, 13 May 2011. While the WENRA stress test proposal only included risks from environmental disasters, Commissioner Oettinger and member states such as Austria want to include terrorist attacks, plane crashes and human error risks. See: http://www.euractiv.com/en/energy/eu-countries-divided-nuclear-stress-tests-news-504812.

13 With the exception of two recommendations by the Commission during the 1960s (65/42/Euratom and 66/22/Euratom) and communication COM(2006) 844 final.

14 Euratom Treaty, Article 98: "Member States shall take all measures necessary to facilitate the conclusion of insurance contracts covering nuclear risks. The Council, acting by a qualified majority on a proposal from the Commission, which shall […] issue directives for the application of this Article."

15 Euratom Treaty, Article 203: "If action by the Community should prove necessary to attain one of the objectives of the Community […], the Council shall, acting unanimously on a proposal from the Commission and after consulting the European Parliament, take the appropriate measures.

16 Directive 2004/35/EC on environmental liability with regard to the prevention and remedying of environmental damage.

Table 1

Overview of the International Regimes for Nuclear Liabilities

International Regimes		Member States	
Paris regime (NEA)	Paris (1960) and Brussels (1963)[a]	Belgium, Denmark, Finland, France, the Netherlands, Germany, Sweden, Italy, the UK, Spain, Slovenia	
		Ratified Joint Protocol (1988)	Denmark, Finland, the Netherlands, Germany, Sweden, Italy, the UK, Spain, Slovenia
		Signed Joint Protocol (1988)	Belgium, France, the UK
	Paris (1960)[a] only	Portugal, Greece	
	Paris (2004)[b]	none	
Vienna regime (IAEA)	Vienna (1963)[a]	Bulgaria, Czech Republic, Estonia, Lithuania, Hungary, Poland, Slovakia, Latvia, Romania	
		Joint Protocol (1988)	All
	Vienna (1997)[b]	*Signed* Vienna (1997)	Czech Republic, Lithuania, Hungary, Poland
		Ratified Vienna (1997)	Latvia, Romania
Convention on Supplementary Compensation for Nuclear Damages (1997)		*Signed*	Lithuania, Czech Republic
		Ratified	Romania
Nothing		Austria, Luxembourg, Ireland, Cyprus, Malta	

[a] First generation; [b] Second generation.

Source: J. Handrlica: Euratom powers in the field of nuclear liability revisited, in: International Journal of Nuclear Law, Vol. 3, No. 1, 2010, pp. 1-18.

Table 2

Nuclear Liability Amounts Available Through the International Regimes

(€ million)

Convention	Who pays?	First generation	Second generation
Paris Convention	Nuclear operator	5.9	700
Brussels Supplementary Convention	Installation State	202.13	500
	Collective State Fund	148.62	300
Total Paris regime		356.7	1,500
Vienna Convention	Nuclear operator	4.2*	178.35
	Collective State Fund		178.35
Total Vienna Convention		4.2*	356.7
Convention of Supplementary Compensation	Operator/Installation State		356.7
	Collective State Fund		356.7
Total CSC			713.4

* (USD 1963 value).

Source: T.V. Borre: Shifts in Governance in Compensation for Nuclear Damage, 20 Years after Chernobyl, in: M. Faure, A. Verheij (eds.): Shifts in Compensation for Environmental Damage, Springer, Vienna 2007, pp. 261-311.

International nuclear law can be characterised by its division between two regimes – the Vienna and the Paris Conventions – which were themselves completed via distinct supplementary conventions but which are also linked through a joint convention which allows mutual recognition of the two regimes. The Paris regime takes place within the OECD Nuclear Energy Agency (NEA) while the Vienna regime takes place within the IAEA. Both regimes have specific rules with respect to liability amounts, definitions of nuclear damage – such as environmental damage – and periods for claims. The latest conventions of the Paris and Vienna regimes can be best described as three-tier systems of strict but limited liabilities: the first tier falls on the operator, the second tier on the installation state and the third tier comes from collective state funds. On top of these two international regimes, the 1997 Convention on Supplementary Compensation for nuclear damage (CSC) allows extra compensation of up to €713 million and more legal certainty. However, Romania is the only EU member state to have ratified this convention. Tables 1 and 2 present the general liability rules and the minimum liability amounts associated with them respectively.

As Table 1 shows, member states differ in terms of the international nuclear law regimes they belong to and in terms of the conventions they have signed or ratified. Generally speaking, we observe that the old member states are part of the NEA regime while new member states from Eastern Europe are, with the exception of Slovenia, part of the IAEA regime. The 1988 joint protocol between the two regimes allows for mutual recognition, but some member states – Belgium, France and the UK – have not ratified this protocol. As Table 2 shows, both generations of the Paris regime foresee higher minimum liability amounts than the Vienna regime. However, only few states are part of the second generation of international liability regimes. For instance, no member states have ratified the 2004 Paris Convention – which amends the 1960 Paris Convention and the 1963 Brussels Supplementary Convention – and increases the total compensation available from €356 million to €1500 million.

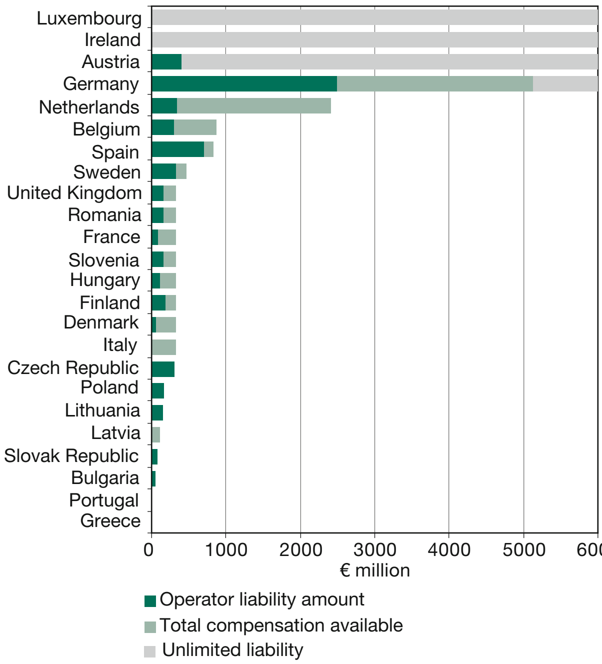
The differences in terms of liability rules arising from the two international regimes are also reinforced by specific national legislation which can be set above the minimum liability amounts of the international regimes. Figure 1 provides an overview of the operator maximum liability amounts as well as the total compensation available from the installation state or international arrangements in EU member states.[17]

As Figure 1 shows, nuclear operator financial securities for nuclear liabilities and the total compensation available vary extensively among member states. Operator liabilities range from €5.4 million in Italy to €2500 million in Germany, and total compensation available ranges from €16.3 million in Greece and Portugal to €5130 million in Germany. Only Germany, Austria, Ireland and Luxembourg have introduced the rule of unlimited liability in their national legislations. Moreover, operator liabilities amount on average to 59% of the total compensation available, with the remainder being shared between the installation state (17%) and international arrangements (24%).

In that respect, EU citizens would not be entitled to the same level of compensation depending on the installation state where the nuclear accident takes place. Moreover, this discrimination is further strengthened by differences in terms of the legal definition given to nuclear damage and claim periods as well as in priority rules for victim compensation.[18] Such discrepancies create clear equality problems which are reinforced by the importance of the trans-border consequences of nuclear accidents.

Are these limits to nuclear liabilities high enough to internalise the risks of nuclear damage? Severe damage in the case of a core meltdown can amount to several dozens of billions of euros in liabilities. At the time of the writing of this paper, investment bank estimates of the damages resulting from the Fukushima accident range from $25 billion to $130 billion.[19] Similarly, while no complete study exists about the costs of the Chernobyl nuclear accident, estimates for the Belarusian economy alone amount to €235 billion.[20] These figures far exceed the national liability systems. The highest level of compensation available in Europe (i.e. in Germany) amounts to €5.1 billion. EU nuclear liability amounts are also low compared to the estimated cost of nuclear accidents based on probabilistic risk assessments. For instance, estimates by

Figure 1
Liability Amounts Available in EU Member States



the EU-financed ExternE project[21] of the expected external cost of a severe nuclear accident range from €431 million to €83 billion. Other estimates[22] give a range of €10-€100 billion.

Hence, by several orders of magnitude, nuclear liability limits in the EU are below the cost of a severe nuclear accident. Economically speaking, this risk is far from fully internalised. Taxpayers will be the main contributors of funds to compensate victims rather than the shareholders of power companies or electricity consumers. The risk is implicitly carried by the state.

In short, nuclear liability rules are set at low levels compared to the expected cost of severe nuclear damage. This leads to important equality problems, as a victim's compensation will depend upon where the nuclear accident happens. Simultaneously, low liability levels might also breach EU economic principles, as they can be viewed as indirect subsidies. One proposal made by economists to solve these two problems

17 OECD: Nuclear operator liability amounts & financial security limits as of December 2009, http://www.oecd-nea.org/law/2009%20table%20liability-coverage-limits.pdf.

18 OECD: Priority rules on compensation for nuclear damage in national legislation as of December 2009. For instance, in Spain personal injury will receive priority over property damage, http://www.oecd-nea.org/law/TABLE%20-%20Priority%20rules%2015%2012%2009.pdf.

19 POWERnews: No Limits for TEPCO's Liability in Fukushima Crisis, Japan Says, 4 May 2011, http://www.powermag.com/print/POWERnews/No-Limits-for-TEPCOs-Liability-in-Fukushima-Crisis-Japan-Says_3686.html.

20 IAEA: Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts, 2005, http://www.iaea.org/Publications/Booklets/Chernobyl/chernobyl.pdf.

21 C. Schieber, T. Schneider: Valorisation monétaire des impacts sanitaires et environnementaux d'un accident nucléaire : synthèse des études ExternE, intérêts et limites de développements complémentaires, in: Rapport No. 275, CEPN, Paris, 2002, http://www.cepn.asso.fr/IMG/pdf/R275.pdf.

22 M.G. Faure, K. Fiore: An economic analysis of the nuclear liability subsidy, in: Pace Environmental Law Review, Vol. 26, No. 2, 2009, pp. 419-427.

is to create an EU pool of nuclear liability[23], which would increase the coverage of nuclear damage and, through the mutualisation of risks, reduce the cost of liability insurance. This system has already been implemented at the state level in Germany and in the United States, where it allows higher levels of compensation. Similarly, it has also been proposed to create an EU nuclear accident pool which reverses the channelling of responsibilities by making member states strictly liable[24] via a risk-sharing mechanism based on expected damage and offers the possibility for the state to delegate some responsibility to the operator. In any case, solutions to remedy the problems raised by the current liability system in the EU are required and economists and legal scholars have to be imaginative.

23 M.G. Faure, K. Fiore: The coverage of the nuclear risk in Europe: Which alternative?, in: The Geneva Papers in Risk and Insurance, Vol. 33, 2008, pp. 288-322.

24 G. Skogh: A European nuclear accident pool, in: The Geneva Papers in Risk and Insurance, Vol. 33, 2008, pp. 274-287.

Conclusion

Through several initiatives, EU institutions have devoted important political efforts to the harmonisation of nuclear safety standards in Europe. Thanks to these efforts, the Commission issued the 2009 directive and established ENSREG. These actions were made in parallel to the creation of the WENRA network which, through a voluntary association of nuclear regulators, has made several proposals to harmonise nuclear safety standards. Following the Fukushima accident, the political difficulty in trying to find agreement on EU stress tests show that political divisions among member states and with the Commission will make further EU binding harmonisation of safety standards difficult. Conversely, liability rules have received little attention despite the clear provisions set by the Euratom Treaty and the failure of member states to set liability rules at a level commensurable to the expected costs of nuclear damage. In that respect, it is urgent for the Commission to reallocate part of its resources and efforts from the harmonisation of nuclear safety standards to the harmonisation of liability rules.

Jaap C. Jansen

In the Wake of Fukushima, Should our Electricity become Almost Completely Renewable and Completely Non-Nuclear?

In the last few years before the Fukushima nuclear disaster, which started to unfold on 11 March 2011, support for the nuclear power option was picking up in several EU member states. New nuclear power plants are currently being built in Finland, France, Bulgaria and other countries; the UK, Sweden, Italy, Czech Republic, Romania and the Netherlands were seriously considering new nuclear reactors, while in Germany, Spain and Belgium a relaxation of the existing moratorium was under political discussion. The commission chaired by former Spanish Prime Minister Felipe Gonzales advising the European Council on the future of Europe stated:

"The search for a more viable energy mix must also involve recourse to nuclear energy. Europe cannot afford to relinquish this important source of power, but unlocking investments in nuclear energy requires a greater level of regulatory certainty, as well as the further development of safety standards."[1]

1 F. Gonzáles Márques et al.: Project Europe 2030. Challenges and Opportunities, Report to the European Council by the reflection group on the future of Europe 2030, May 2010.

Yet all over the world, not least in Europe, the Fukushima nuclear accident has given politicians and energy policy analysts food for thought in reassessing the role of nuclear energy and renewables in their long-term energy policies. The first government to radically revise its energy policy regarding the deployment of nuclear power reactors was the German coalition government of Christian Democrats and Liberals, led by Angela Merkel. Mrs. Merkel had already made up her mind on 12 March 2011: she ordered the 7 oldest of Germany's 17 nuclear energy plants to be switched off "for the time being" for three months.[2] At the same time, she revoked the decision approved by the German Parliament on 28 September 2010 to extend the operational lifetime of nuclear plants by an average of 12 years relative to the moratorium plan promulgated in 2002 by the Social Democrat/Green Party coalition government. To that effect, she installed an ethics commission that has to submit a report with a proposed date for the complete demise of German nuclear power generation. According to leaked information, this will be no later than ten years from now, i.e. by 2021. At the time of writing this article, the governments of the other 14 EU mem-

2 Der Spiegel: Das war's!, No. 14, 2011, pp. 62-72.

ber states with operating nuclear energy plants did not go further than to announce ad hoc audits that should integrate the lessons learnt from Fukushima. Yet among the remaining member states without operating nuclear reactors, Italy has put the intended reintroduction of nuclear power generation capacity on hold.

This article presents a preliminary qualitative assessment of a fast phase-out of nuclear electricity capacity and a transition towards a largely (80%+) renewable electricity supply sector in Germany and the greater EU. The focus is on the associated costs and the feasibility of the envisioned transition towards a completely renewables-based electricity supply sector. Special attention is paid to Germany as this country is pioneering an *Energiewende* (a fast transition towards a renewables-based energy economy). Moreover, it has a large power sector accounting for about 30% of EU power demand. The article is structured as follows. First, three politically important scenario studies are briefly introduced which have developed (among others) scenarios for an 80%+ renewable power sector in Germany and the EU by 2050. Next, the most important conditions for making such scenarios come true are reviewed. Finally, the major consequences of a political decision to introduce or speed up a nuclear moratorium in EU member states will be addressed. The article closes with conclusions.

Making Power More Renewable: Some Scenarios

To date, the most relevant scenarios for energy policy formulation in Germany are the scenario study[3] underlying the Energy Concept policy document[4] of the German government and a study commissioned by the Federal Ministry of the Enviroment in 2010 (Pilot Study 2010).[5]

The scenario study for the Energy Concept develops target scenarios for reducing GHG emissions in Germany by 85% by 2050 relative to 1990. Moreover, in the target scenarios, primary energy demand and electricity demand in 2050 relative to the base year 2008 are to be reduced by more than 50% and by 20-25% respectively. In the target scenarios, renewable-based electricity, including substantial renewable electricity imports, are to account for around 80% of gross electricity demand by 2050. By then, an important non-renewable power component would be coal-based power in CHP (combined heat and power) mode with CCS (carbon capture and storage). Some of the major points envisaged by the aforementioned target scenarios include the following:

- Wholesale electricity prices in 2050 will be in the order of €20-30/MWh[6] as opposed to spot prices which currently oscillate within the €55-65/MWh range. Saharan solar power will exert a substantial downward effect on wholesale power prices, especially during the mid-day peak hours.
- In 2050 the unit cost of electricity (generation cost only) will be about €15/MWh higher than in 2008. The major reason for the increase is the expansion of renewable electricity generation.
- Offshore wind will be the renewable option providing the largest contribution to the increase in renewable electricity generation, with other – e.g. biomass-based – options being constrained by factors such as biomass or land availability.
- In Germany photovoltaics (PV) will not become economically feasible by 2050 in spite of learning curve effects. Feeding in at lower network voltage levels hardly saves network costs, as these are more than 90% determined by fixed costs.
- The *EEG Umlage* (surcharge on the household electricity bill to pay for the extra costs of renewable electricity stimulation by the German feed-in tariff system) will be approximately €0.04/kWh in 2050.
- The household electricity price in 2050 will be approximately €0.22/kWh, i.e. broadly the same level as at present.

The Pilot Study 2010 analyses renewables-dominated energy futures for Germany through 2050. One of the scenarios presented in this study projects a 100% renewable-based power supply sector. Its baseline demographic, structural and economic assumptions correspond largely to the ones used in the Energy Concept scenario study. As a result of assumed increasing primary energy productivity, electricity is to gradually diminish through 2030 and level off thereafter through 2050. Hence the reduction in power demand from 2008 to 2050 in the Pilot Study 2010 scenarios is much less than in the Energy Concept target scenarios. According to the Pilot Study, power demand by "new uses" such as electric vehicles, heat pumps and air conditioning are bound to largely offset electric energy efficiency improvements. In the 100% renewable electricity scenario, hydrogen production for electricity storage purposes would even push total electricity demand in an upward direction. Balancing options to be implemented for stabilising the electricity system include: (1) grid extensions, (2) the provision of new storage capacities, and (3) generation and load management. Controllable renewable power such as biomass, including biomass for flexible CHP (with heat or gas storage opportunities), pumped-storage and H_2-powered plants as well as inter-

3 Prognos/EWI/GWS: Studie Energieszenarien für ein Energiekonzept der Bundesregierung, Basel/Köln/Osnabrück, August 2010.

4 Bundesrepublik Deutschland: Energiekonzept, BMWI/BMU, Berlin, 28 September 2010.

5 DLR/Fraunhofer IWES/IfrE: Leitstudie 2010, Study commissioned by BMU, December 2010.

6 Unless otherwise stated, monetary values mentioned in this article are "real", i.e. not including future price inflation.

national electricity exchanges, are primarily to be used for load management. Because of the high share of intermittent renewable generation with priority grid access, the need for base-load power plants is set to diminish. Generation costs of renewables-based electricity in Germany would come down from €0.14/kWh in 2011 to €0.06/kWh in 2050. Note that transmission and distribution costs are not included in these amounts. Given projected trends, within the period 2025-2032, all-renewables power generation would become cheaper than power generation according to the baseline scenario, i.e. a scenario in which conventional power still makes up an appreciable share.

At the time of writing, the European Commission has not yet presented scenarios with a time horizon as far off as 2050.[7] Therefore we now briefly discuss Roadmap 2050 scenarios with a largely renewable-based European power supply sector based on a study prepared by a well-regarded source, the European Climate Foundation (ECF).[8] The study concerned uses as its point of departure an 80% CO_2 reduction in the EU[9] by 2050 relative to 1990. This equates to a 95-100% non-CO_2 electricity generation mix. The "pathways" (backcasting target scenarios) considered include ones with a 40%, 60% and 80% renewable electricity share (RES). The non-renewable shares are assumed to be equally divided between fossil fuels with CCS and nuclear power. At the EU level, power demand is set to grow by about 40% from 2005 to 2050 under low carbon pathway conditions. This is similar to the Roadmap 2050 baseline scenario without intensified climate change policy: extra energy efficiency improvements would be offset by extra demand for electricity due to "new uses" such as electric vehicles and space heating by electric heat pumps. The ECF study concludes that if the presumed framework conditions were met, the cost of electricity for the three low-carbon pathways could be 10-15% higher than the baseline excluding carbon pricing. At a carbon price of €20-30/tCO_2eq, the cost of electricity of the three low carbon pathways and under the baseline scenario would be roughly the same. However, the overall cost of energy would decline by 20-30% relative to the baseline, due primarily to greater energy efficiency and a shift from oil and gas to decarbonised electricity in transport and buildings. If a low carbon pathway of 100% electricity from renewable sources in the electricity mix were to be pursued, this would be feasible technically and at a cost of probably only 5-10% more than the 60% RES pathway.

7 The European Commission communication: Energy 2020, a strategy for competitive, sustainable and secure energy, COM(2010)639 final. Brussels, 10 November 2010, falls short of presenting detailed scenario results.

8 EFC: ROADMAP 2050, practical guide to a prosperous, low-carbon Europe, Berlin, Brussels, The Hague, April 2010.

9 Apart from the EU27, Norway and Switzerland are also included.

General Framework for High Renewable Power Scenarios

The three studies reviewed all come with an invariably happy message: end-user electricity prices will hardly rise or (e.g. according to the Pilot Study 2010) may even fall if a high energy efficiency (EE) cum renewable (RES) power scenario is adopted to support long-term energy policy. A moratorium on nuclear energy would not materially affect this forecasted upshot. This "happy news" is compounded by some of the major benefits an EE/RES scenario has relative to a business-as-usual scenario:

- carbon emissions will decrease by substantially higher amounts;
- supply security will be much greater as dependency on imported fossil fuels from politically less stable countries will decrease markedly;
- electricity prices will become more stable;
- innovation will lead to job creation.

Some qualifying remarks can be made concerning the presumed general framework. First, let's examine some of the major conditions. Future prices of coal and natural gas will have a major impact on the future fuel mix in the electricity sector. Rising fuel prices improve the competitiveness of both nuclear and renewable energy. Future fuel prices are surrounded by great uncertainty, yet it would seem likely that strong long-term upward trends for fossil fuel prices are in the offing. For supply to meet fast increasing non-OECD demand, marginal supply has to come from increasingly expensive sources. Regarding the market for internationally traded coal, it is often overlooked that supply concentration is quite high. Countries with major coal resources, such as the USA, China and India, need virtually all their production to meet their domestic demand. As for gas, non-conventional gas is often touted as a "game changer". Indeed, current gas prices are somewhat depressed, though it is a distinct possibility that this situation could last for only a few years. A major reason for this is that gas is the fossil fuel of choice due to its fairly moderate environmental impact – including its carbon emissions impact – compared to coal. Moreover, the investment costs of gas-based power plants are low, while their construction period is short.

Therefore, it would seem prudent for scenario developers to assume quickly rising fuel prices as well as a high correlation among oil, gas and coal prices, i.e. the rise in coal prices will not be substantially less steep than the others. Table 1 shows the assumptions made for the scenarios introduced above. The price paths A of the Pilot Study 2010 would seem most appropriate. The Roadmap 2050's reliance on IEA figures for coal seems rather off the mark, as the coal market in coal-importing Europe is quite different from non-Europe OECD.

Table 1
Assumed Price of Coal and Natural Gas in the Scenarios Considered
(€/MWh)

		2008	2030	2050
Coal	Scenarios for Energy Concept	17.3	10.8	14.0
	Pilot Study 2010: path A	13.7	23.4	33.1
	Roadmap 2050[a]	6.1[b]	7.9	9.4
Gas	Scenarios for Energy Concept	25.2	25.9	31.7
	Pilot Study 2010: path A	26.3	49.7	69.1
	Roadmap 2050[a]	21.4[b]	25.2	35.6

[a] US $1 = €0.704. Figures are based on the IEA World Energy Outlook 2009; [b] Figures for year 2009.

Sources: Prognos/EWI/GWS: Studie Energieszenarien für ein Energiekonzept der Bundesregierung, Basel/Köln/Osnabrück, August 2010; DLR/Fraunhofer IWES/IfrE: Leitstudie 2010, Study commissioned by BMU, December 2010; EFC: ROADMAP 2050, practical guide to a prosperous, low-carbon Europe, Berlin, Brussels, The Hague, April 2010.

Table 2
Assumed Parameter Values for Cost of Electricity from Offshore Wind

		2010	2030	2050
Investment cost (€/kW)	Scenarios for Energy Concept	2400[a]	1670	1350
	Pilot Study 2010	3300	1800	1300
	Roadmap 2050	3000 -3600	2000 -2400	1900 - 2300
Running cost (€/kW-year)	Scenarios for Energy Concept	132[a]	92	74
	Pilot Study 2010	182	99	72
	Roadmap 2050	80-100	80-100	80-100

[a] Figures for 2020.

Sources: Prognos/EWI/GWS: Studie Energieszenarien für ein Energiekonzept der Bundesregierung, Basel/Köln/Osnabrück, August 2010; DLR/Fraunhofer IWES/IfrE: Leitstudie 2010, Study commissioned by BMU, December 2010; EFC: ROADMAP 2050, practical guide to a prosperous, low-carbon Europe, Berlin, Brussels, The Hague, April 2010.

Second, apart from large hydro and a few biomass power generation technologies in limited biomass-rich regions, renewable power technologies cannot yet compete on a commercial basis with conventional sources for grid electricity. This may well change for a variety of renewable generation technologies as a result of technological learning. In all high-RES scenarios for the future power supply in Germany and Europe, the key technology that is forecasted as the largest domestic contributor to incremental renewable power generation is offshore wind. Should the forecasted growth of power generation from offshore wind not materialise, then the goal of an electricity mix including 80%+ renewable electricity by 2050 will be very hard to achieve.

Table 2 shows key assumptions regarding the future cost evolution of electricity from offshore wind. The offshore wind running cost assumptions made by the two German studies seem reasonable, as experts point to a large scope for economies of scale and technological learning in the operation of offshore wind parks. In contrast, the assumed investment costs of €1300-1350/kW in 2050 would seem rather (overly) optimistic, even with the sharing of seaborne connecting cables, as opposed to the more realistic €1900-2300/kW assumed by Roadmap 2050. Material inputs such as steel, copper and rare earths such as neodymium provide a solid lower limit to the level of cost reductions that can be achieved. Moreover, with the number of offshore wind parks increasing, locations for new parks will be further from shore and in deeper waters, which escalates total investment cost. We note that optimistic "learning" assumptions like the ones described have a large impact on the results of "happy news" scenarios on long-term energy futures.

Third, all three studies assume an EU-wide stringent climate policy resulting in clearly rising carbon prices. High carbon prices favourably affect the competitiveness of both nuclear and renewable power. Indeed, the EU emissions trading system is a precious instrument to be retained and further strengthened in order to cost-effectively render the European economy less carbon-intensive. Yet the political feasibility of a stringent European climate policy strongly depends on whether or not credible climate policies are introduced elsewhere in the world as well.

Fourth, another common assumption is that massive investment in expansion (by roughly a factor of three by 2050 compared to what is currently in place) and closer integration of the transmission networks in the EU and the Maghreb occurs.[10] This is a difficult condition, both in terms of the financial requirements and implementation efforts. As the Roadmap 2050 study rightly points out, in order to achieve energy transitions to low-carbon power systems, such as 80% renewable power systems, there is no time to lose in quickly reinforcing European electricity networks. However, the EU-wide BANANA[11] syndrome is exerting a strongly negative impact on transmission network expan-

10 This is absolutely necessary to address the system stability issue, given a fast increase of intermittent renewable electricity such as wind power in particular but also PV and wave power. Moreover, it enables cost-reducing competition between a multitude of European suppliers and generation technologies as well as the location of renewable power at sites with the lowest-cost resources in Europe (e.g. wind power in Western Europe, solar power in Southern Europe and the Maghreb, and bio power especially in Central and Eastern Europe).

11 Build Absolutely Nothing Anywhere Near Anyone.

sion. For example, the current expansion of the German transmission network falls seriously short of what the German Energy Agency (DENA) has identified as necessary to accommodate the expansion of wind power capacity. This will increase not only the volume of forced curtailment because of network constraints but also the risks of lesser network security in Germany and neighbouring countries. On the other hand, allowable returns on network investments in Germany in the order of 7% per annum do not encourage private-sector investors such as pension funds to allot equity capital to new network expansion projects. To solve the implementation problems in a timely manner, if at all possible, large budget overruns are likely. Furthermore, massive investments are needed to reinforce electricity distribution networks, enabling bi-directional power flows.

Fifth, it is assumed that the use of intelligent networks will become a common operational practice. These are badly needed to cope with network stability issues in the face of the high penetration of intermittent renewable power. Again massive financial investment is required for ICT hardware and software, the upgrading of networks as well as human capital. Additionally, wide-ranging European harmonisation in network regulation and regulatory reforms have to be put in place, enabling e.g. time-dependent end-user tariffs, also for households, and time- and location-dependent market stimulation of renewable power. For example, regulators might consider stimulating renewable power only during hours in which non-negative electricity wholesale prices occur and at locations where no network congestion takes place. Furthermore, in countries where renewable power commands a non-negligible share of the electricity mix, priority rules for renewable power can negatively affect market efficiency. For example, in these respects the German feed-in tariff system is strongly at odds with the introduction of "smart grids".

Finally, the emergence of a truly EU-wide electricity market is assumed. Similar to and contingent upon robust and strongly interconnected transmission networks, this is to enable price-reducing competition throughout the EU. Additionally, it helps to facilitate exports during times of peak production by intermittent renewable power plants and, conversely, cross-border imports at times of low domestic production by such plants. It is indispensible that, as assumed in the German study on scenarios for the Energy Concept, a transition will occur towards a technology-neutral renewable electricity support system that is harmonised throughout the EU. The assumed continuation of the German feed-in tariff system in the Pilot Study 2010 will hinder cost-reducing competition between renewable technologies and the EU-wide location of renewable power plants at the sites with the lowest-cost renewable resources. The consequence of the latter assumption becoming a reality would be a dramatic rise in the costs necessary to achieve an 80%+ renewable electricity supply system.

What Will Be the Consequences of a Nuclear Moratorium?

As already noted, the German government was remarkably fast in concluding that the Fukushima incident presented sufficient critical evidence to repeal a recent decision to extend the lifetime of the 17 existing German nuclear reactors and to consider an accelerated moratorium. The website of the BMU, the German ministry responsible for nuclear reactor safety, explains that the Fukushima accident denotes a game-changing event for Japan and the whole world. The BMU concludes that it has changed the security situation for German nuclear reactors, as the unfolding Fukushima accidents have shown that (catastrophic) events can occur beyond what is foreseen in the currently considered scenarios.[12] Many researchers corroborate this BMU reasoning, arguing that Fukushima demonstrates that the residual risk of a nuclear catastrophe leading to radioactive contamination of the environment as a result of a nuclear reactor meltdown is much higher than was generally assumed beforehand.[13] We shall avoid the question of whether this reasoning is true or not. We consider instead the consequences of introducing a(n accelerated) nuclear moratorium in EU member states or at the EU level.

In the medium and long term, the world is poised to face severe constraints throughout the entire energy supply sector. This will not only affect the supply of fossil fuels with concomitant rising fossil fuel prices. Renewable electricity and other renewable energy carriers will also face stringent supply limitations.[14] If this scenario holds true, as I believe it will, what would be the consequences of a European moratorium on nuclear power and a strong push towards achieving an 80%+ renewable power supply sector by 2050?

12 See http://www.bmu.de/moratorium/doc/47140.php: Fragen und Antworten zur Sicherheitsüberprüfung aller Deutschen Kernkraftwerke, download 22 May 2011.

13 Marcel Viëtor explains the German acronyms "GAU" and "super-GAU" for such incidents in his article dated 17 March 2011 on the website of the European Energy Review, http://www.europeanenergyreview.eu: Assumptions and accidents. He concludes that a super-GAU remains thinkable and questions whether governments and societies in the EU are willing to accept this risk. In answering this question, the European public has a right to unbiased information on whether the events in Chernobyl and Fukushima have had a material impact on expert opinions on the residential risk of nuclear reactors in the EU. As for Fukushima, there are still a lot of questions e.g. about nuclear safety supervision and implementation performance regarding severe accident precautionary measures that remain to be answered.

14 P. Mortiary, D. Honnery: Is there an optimum level for renewable energy?, in: Energy Policy, Vol. 39, 2011, pp. 2748-2753.

A moratorium on nuclear power would reduce and eventually remove the residual risk factor of exposing the European peoples to nuclear contamination as a result of accidents with nuclear reactor meltdowns within EU territory. It is a political choice whether this benefit should be pursued or not. Yet it should be realised that a nuclear moratorium comes at an economic price. A nuclear moratorium would further tighten the supply constraints of the European electricity supply sector. This is even more the case if the pursuit of ambitious European GHG reduction policy targets such as an 80% GHG reduction by 2050 are continued. Many authoritative publications by organisations such as the IEA and its NEA subsidiary indicate that the full costs of nuclear electricity are relatively low, even when factoring in investment cost escalation, reasonable costs for decommissioning, disposal of spent fuel and a fair premium for residual risk. Hence discarding the nuclear energy option has a non-negligible upward impact on the cost of electricity, which is already likely to rise anyway.

Furthermore, a moratorium acceleration which entails the premature decommission of some reactors before they have served out their economic lifetimes would typically result in a multi-billion euro amount of capital destruction. Consequently, nuclear operators would be negatively affected. As an alternative, governments could appropriate a substantive portion of the capital saved by avoiding the acceleration of a moratorium via case-specific taxation. This money could help to foot the staggering bill of energy transition implementation.

Concluding Remarks

An 80%+ carbon reduction in the power sector by 2050 will require a combination of:

- fossil fuels-based power generation with CCS;
- a shift from coal to gas;
- a significant reduction in the demand for electricity, coupled with an even stronger reduction in the demand for non-electric energy;
- the fast penetration of renewable power;
- a significant contribution from nuclear power.

None of these options can be dismissed if stringent carbon reduction targets are to be achieved. Apart from CCS, which has its own implementation problems and still needs to prove its viability, a shift from coal to gas in the power sector can offer only moderate carbon reduction. Furthermore, a more prominent role for gas in the electricity mix will increase Europe's dependence on gas imports. Yet even with a renewable share in the electricity mix, a role for gas in balancing the electricity system remains likely.

Further electrification of the European energy economy can have important benefits in terms of making our society more energy-efficient and consequently carbon-efficient. The penetration of electric vehicles, including plug-in hybrids, and efficient heat pumps for space heating will impact negatively on primary energy demand. Moreover, the production of hydrogen through electrolysis may eventually help to address the problem of managing electricity system stability. Nonetheless, the severe energy constraints looming at the world level and the climate change problem render technical fixes in the way of energy efficiency-boosting measures very necessary but still insufficient. Hence, an absolute reduction in total electricity demand and more importantly in total energy demand at large would seem a quite appropriate top energy policy target for affluent OECD societies. Therefore, as such, the German energy policy targets as outlined in the Energy Concept are laudable.

However, the scenario analyses underlying this policy document suggest that the reduction targets for electricity can be achieved without any increase in end-user electricity prices. This is a less credible outcome. To bring about the drastic lifestyle changes that will be necessary to achieve the Energy Concept targets for electricity and energy reduction, end-user electricity and non-electric energy prices will have to go up substantially. Politicians and energy policy researchers in Europe had better begin informing the general public that the days of cheap energy are most probably gone.

The goal of achieving the fast penetration of renewable electricity in the electricity mix deserves a high energy policy priority. Renewable energy, including renewable electricity, has some innate advantages apart from carbon reduction that are worthy of dedicated energy policy attention. Yet achieving 80%+ renewable electricity by the 2050 target date will add much more to the electricity bill than the results of the energy scenario analyses considered in this article would lead us to believe. Moreover, real world inertia renders this target hardly implementable at all. An EU-wide renewable electricity target in the order of 40-50% by 2050 would seem more realistic and affordable while still quite ambitious.

If nuclear energy were to be removed as a politically non-feasible option, this would make the achievement of ambitious European climate change targets all the more expensive. Moreover, it would boost imports of natural gas and coal, which is at odds with the political goal of improving the security of supply. It is up to the political domain in the EU and its member states to weigh these economic aspects against the intrinsic disadvantages of nuclear power, including the residual risk issue. The availability of impartial, non-politicised information on the pros and cons regarding the nuclear power option should assist a fair debate, ultimately leading to well-reasoned outcomes of the political decision process.