VULNERABILITY AND RESILIENCE IN THE EUROPEAN ENERGY SYSTEM

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INTRODUCTION

The need for deep cuts in global emissions of GHGs (greenhouse gases) to avoid dangerous climate change recognised in the Bali Action Plan is welcome [1]. Hopefully the "Road to Copenhagen" will be strewn, not just with good intentions, but with positive actions that will lead to real and meaningful cuts. This will be a challenge as demand for energy looks likely to continue to rise. Without intervention GHG emissions are expected to increase by 50percent between 2004 and 2030. Though most of the growth will be in the developing world, per capita demand will remain high in OECD (Organisation for Economic Cooperation and Development) countries. Despite recent rapid fluctuations in oil and gas prices and the economic recession, in the longer term prices are likely to recover and continue to rise and this will either encourage low carbon technologies or a reversion to coal and other unconventional hydrocarbons. The latter is likely to exacerbate GHG emissions [2].

Energy, both for power and mobility, is essential for societal development. Energy policy must ensure secure and affordable energy services, address climate policy targets and contribute to sustainable development objectives. Meeting these multiple objectives is an immense challenge. It becomes even more problematic without the appropriate framework. This is a problem for the EU. In terms of energy policy the EU lacks specific competence and has used competences in competition policy, the internal market and the environment to shape energy policy. Article 176A of The Lisbon Treaty, expected to come into force in 2009, represents a significant step towards a common EU energy policy. Whether this will lead to a sustainable energy policy is too early to judge. However the mix of measures set out in *An Energy Policy for Europe* are likely to increase the vulnerability of an already vulnerable system and fail to meet the multiple objectives required of energy policy.

VULNERABILITY AND THE ENERGY SYSTEM

An Energy Policy for Europe envisages an EU-wide interconnected system for gas, oil and electricity that will provide secure and affordable energy services for its citizens [3]. Lack of specific institutional competence for energy policy requires the Commission to use alternative pathways to meet objectives. These are broadly marketisation of the supply system to ensure cost-effective supplies, carbon trading, continuing support for renewables together with external agreements to secure access to supplies and ensure security of supply. In the EU, energy systems have developed within member states to meet national goals[1]. Interconnecting these systems is a technical and political challenge. Complex interconnected systems are intrinsically vulnerable and this can be exacerbated by internal and external dynamics.

INTERNAL DYNAMICS AND VULNERABILITY

Complexity or tight coupling in technological systems generates vulnerabilities. No matter how effective conventional safety devices are in technological systems, accidents are inevitable, with catastrophic potential. Examples of systems that have catastrophic potential include nuclear power plants and ships carrying explosive cargoes such as LPG. Tight-coupling can result in errors, either in design or operation that leads to accidents [4].

The complexity of interconnected electrical systems has unintentionally increased their vulnerability [5]. Interconnected electrical systems are complex spatially dispersed systems reliant on a series of generators interconnected to a distribution grid to deliver power to users. Failure or compromise of one part of the system can have knock-on effects. The near black-out in Europe in November 2006 was due to a combination of cold weather increasing demand and part of the system temporarily out of use to allow the passage of a vessel along a waterway. This cascading effect ultimately can lead to collapse. Factors that stress the system and contribute to increasing frequency of blackouts are steady increases in load and economic pressures to maximise grid use [6]. Deregulation, driven by competition for lower prices and efficiencies, requires complex interaction between an increasing number of agents in different markets (such as energy, capacity, ancillary services and transmission rights) and in multiple time frames (such as futures, day ahead and real time). An electrical power system is a single entity and requires real time coordination. This is even more problematic when markets operate across national borders where systems and operating procedures may differ [7]. Close coordination between different systems operators is needed to maintain network integrity in times of high demand or disruption to part of the system. The Italian blackout in 2003 is attributed to lack of co-ordination between national operators following the loss of interconnection capacity in Switzerland [8].

The structures of energy systems in Europe have their origins in state monopolies. Despite privatization and other steps designed to meet free market ideals, there is still evidence that the hand of the state, through a variety of mechanisms, is actively trying to shape the energy industry in the best interests of national goals [9]. Studies of the electricity sector, show that full liberalization has yet to be completed anywhere in the world and seems unlikely for the foreseeable future [10]. One difficult set of issues that will need addressing in the formulation of an effective market is the imbalance in support for the conventional and nuclear sectors as compared with the renewable sector and pricing structures that do not reflect the external costs, in terms of health or

[1]An energy system is described as the resource base, transformation technologies, delivery infrastructure and equipment that provides user services, service providers and service users.

environmental damage, for fossil and nuclear fuels [11] [12] [13] [13]. The answer to the question of whether these distortions would be addressed in the interests of EU solidarity remains unclear and raises questions about the equity of the single energy market.

Markets, either left to their own devices or poorly realised, frequently fail, particularly with regard to social and environmental benefits and costs that might be associated with certain types of energy activities [15]. This risks conflict with the sustainable development objectives of the EU. If market distortions are not addressed, then the cost benefits are unlikely to be fully realised, damaging economic performance and placing additional burdens on poor and vulnerable households. In terms of climate policy market distortions mean that the cost of global warming are not borne directly by greenhouse emitters and that technological innovation is likely to inhibited or slowed [16] [17].

In terms of meeting international climate targets, the progress to date is not encouraging. The EU seems unlikely to meet even the modest Kyoto targets, with significant growth in carbon emissions from transport and household sectors. Increased energy efficiency and additional renewables can contribute to targets. But it seems unlikely that targets for either will be met [18]. This means that the EU will continue to rely heavily on the flexibility mechanisms to meet its Kyoto targets [19:177]. To what extent the EU Emissions Trading Scheme (ETS), launched in 2005, which covers almost half of the EU carbon dioxide emissions, is able to contribute to the new reduction targets proposed in *An Energy Policy for Europe* is too early to predict, but the signs are not promising. The EU ETS relies for its effectiveness on the allocation plans set by governments. Early in 2006 carbon prices fell, an indication of the problem of the scale of allocations [20]. National Allocation Plans, the vehicle by which governments allocate carbon targets, were set, in a number of cases, too generously, lowering the carbon price. This militates against the scarcity principle, essential for a robust market, and casts doubt on the willingness of the EU members to meet international climate commitments and seriously undermines the credibility of carbon trading as an effective carbon reduction mechanism [21]. In January 2008, the European Commission proposed a number of changes to the scheme, including centralized allocation by an EU authority, auctioning a greater share (60+ %) of permits rather than allocating freely and inclusion of the greenhouse gases nitrous oxide and perfluorocarbons [22]. At time of writing the carbon market has all but collapsed and there are suggestions of setting a floor price. Perhaps we should listen to the advice of Jim Hansen and the CEO of Exxon and impose a carbon tax. Blind adherence to a failing market system could weaken EU internal dynamics and increase vulnerability.

EXTERNAL DYNAMICS AND VULNERABILITY

The EU is increasingly dependent upon external supplies with some 70 per cent imported by 2030 [23].Though the geopolitical aspects of Europe's external energy policy remain within the competence of member states' foreign policies and a matter of national sovereignty, the EU does have competence to deal with commercial relations with non-EU countries. Conventional supplies are unevenly distributed across the globe and to ensure ongoing access the EU has launched a series of dialogues, agreements and projects, using its commercial relations competence, as the vehicle. Dialogues are ongoing with Russia, OPEC (Organisation of Petroleum Exporting Countries) and Norway, with neighbouring states to the south and east under the umbrella of the European Neighbourhood Policy [24] and through cooperation agreements such as the Baltic Sea Region Energy Cooperation (BASREC) and projects such as the Baku-Tbilissi-Ceyhan (BTC) oil pipeline. Until recently there has not been a direct threat to EU energy security emanating from the difficulties between Russia and its neighbouring countries [25][26]. The recent difficulties between Russia and Ukraine may be a harbinger of the future.

The vulnerability of agreements, both current and future, to geopolitical uncertainties provides fertile ground for political scientists to explore. However the vulnerability of the external infrastructure to disruptions is evident. The EU is dependent on a network of gas and oil pipelines as well as maritime infrastructure. Pipelines are vulnerable to natural hazards such as earthquakes and to extreme weather events driven a changing climate. Other energy infrastructure is also vulnerable to climate change. In 2003 heat wave a number of nuclear reactors in France had to shut down due to a lack of cooling water. Globally, some 60percent of energy supplies are transported by ship, vulnerable to both extreme weather events and accidents. But of equal concern is the disruption that could be caused by terrorist attacks. Small, highly motivated groups could cause severe damage to port facilities as well disruption by attacking critical chokepoints such as the Straits of Hormuz and the Suez Canal. Disruptions of this kind would have a catastrophic impact on the energy markets [27] [28]. Land-based supply infrastructure is equally vulnerable to terrorist attacks.

Though many will agree the necessity of securing access to supplies, this can only be a temporary measure. There is considerable debate about the longevity of conventional energy supplies with the timing of Peak Oil (the date at which the world starts to produce less than it consumes) ranging from the beginning of this century to the middle, or beyond, though unconventional supplies (oil shale, tar sand and heavy oil) can extend this the period before the peak occurs [29]. Similar predictions have been made for gas. An analysis by Bentley claims that peak oil will occur prior to 2015 and peak gas before 2030 with the global peak for hydrocarbons occurring before 2020 [30]. It is not within the scope of this paper to forecast when this peak will occur. But the potential for price instability introduces a further vulnerability with forecasts that the global demand for oil will be grow by some 40 percent by 2030 [31]. At time of writing oil prices in excess of US$120 per barrel are having significant impacts in the EU.

Reducing the vulnerability of the EU Energy requires policy interventions that steer the direction of development towards embedding resilience. Resilience in the energy system is usually narrowly defined in terms of either reliability or durability. A more holistic perspective can enable the use of the concept of resilience as a vector for shaping energy policy.

RESILIENCE AND ADAPTIVE CAPACITY FOR ENERGY SYSTEMS

The resilience perspective has emerged as a characteristic of complex and dynamic systems in a number of disciplines including ecology, economics, sociology and psychology [32] [33] [34] [35]. The resilience perspective is increasingly used in the analysis of human–environmental interactions [36]. The study of coupled human-environment systems, range in scale from local to global, constituted by the whole of humankind (the "anthrosphere") and the ecosphere [37:294]. A resilient system has the capacity to absorb disturbance and reorganise and retain essentially the same function, structure, identity, and feedbacks [38]. Conceptually, resilience is not focused on what is missing (needs and vulnerabilities) but on what is present (resources and adaptive capacity) [39. A resilient system will act to reduce vulnerabilities. Resources and adaptive capacity are the knowledge, skills, physical resources and the ability to recognise and act to minimise vulnerabilities.

Energy systems function from the local (demand) through to the global (supply). The human-environmental interactions of energy systems are both the acquisition and transformation of energy supplies into services, the use of those services and the environmental impacts associated with the overall process. Resilience in the energy system is traditionally seen from an engineering perspective as robustness and is focused on the ability of the system (meaning the technological systems, infrastructure, logistics, managerial and technical expertise involved in delivering energy services) to recover from disturbances. This is a narrow top-down perspective. A resilient system approach has a holistic perspective with both top-down and bottom-up approaches acting synergistically as antidote to vulnerability.

Conceptually a resilient energy system acts to reduce vulnerabilities by using indigenous and renewable resources and transforming these into needed energy services. Renewable resources are diffuse and intermittent and usually have lower energy densities. As opposed to "supply-on-demand," a renewable approach requires "capture-when-available" and "store-until-required" strategies. There are exceptions, such as hydro-electric schemes, but typically renewable systems function best at small-scales near to point of use. They are not focused on a particular fuel type but use indigenous resources [40]. Though a renewable approach is vulnerable to source with intermittency, it does not have the same vulnerabilities associated with the current system. Resilience is a drive to de-centralisation. It is a participative effort that requires the engagement of all stakeholders. It is not technologically driven but emanates from a combination of messages, actions, incentives, exemplars and on-going institutional commitment. It builds on societal capacity to change and adapt. The starting point for a resilient energy system is the household [41]. By using technologies that produce energy services near to the point of need, it acts to make households an active part of the energy system. The intimate relationship between energy and climate policy means households will become co-producers of climate-change solutions. Households produce about one third of greenhouse gases in the EU. A combination of renewable technologies, passive building technologies and energy efficiency should make a considerable impact. Extending the principle further to the public and private sector and transport systems will make further inroads.

The drive towards decentralization reflects technological developments and shifts in the ways that energy technologies are increasingly being used. Decentralized or autonomous energy systems are not a new concept, but are becoming a feature of many mainstream functions, with many organisations, both public and private, using back-up, standby or autonomous systems to protect critical infrastructure and functions [42]. Electricity supply-side technologies are becoming smaller, smarter and more flexible. The need for large grids to transport power is less viable and may be redundant in the future [43]. Large-scale supply-side technologies, such as nuclear power, rely on economies of scale. They lack flexibility and require a large-scale interconnected grid with its associated vulnerabilities and are a technological dead-end [44]. Others advocate carbon capture and storage (CCS) but this has a narrow supply side focus, offers little in terms of radical technological shifts and is unlikely to be commercially viable before 2020. We need to think differently.

Shifting the Direction

Shifting the direction of an energy system, particularly the mature systems of the EU, requires both effort and time. Figure 1 illustrates how the present development trajectory of the EU energy system needs to change. The time t shown in Figure 1 is the window, 10 to 20 years, within which actions are needed to start the process of stabilising greenhouse gas concentrations at a safe level, generally acknowledged as being between 400 and 550 ppm CO2e, by 2050. The longer the delay in beginning the process the more radical, and difficult, future actions will become [45]. Technology will play a vital role but, of itself, cannot solve the problem. There has to be shift in public attitudes and values towards global environmental concerns [46]. Technology is a social construct and requires interventions that will steer development in paths that meet desired public goods. This will be an immense learning challenge from the individual through to the institutional level.

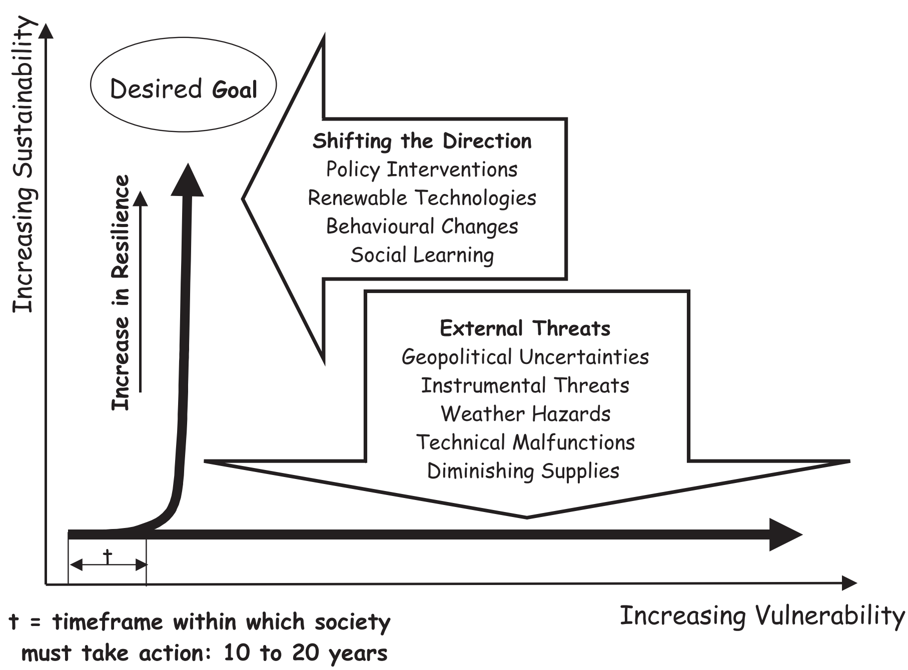

Figure 1. Shifting the Direction

The triple win, making each of us co-producers of solutions to energy security, mitigating climate change and reducing environmental degradation, should be the focus of energy policy. *An Energy for Europe* does point out two of the approaches to a triple win, increased efficiency and renewables, but neglects the third, the mix of interventions that would actively encourage a greater participation by users. *An Energy Policy for Europe* is worryingly quiet about the need for, and ways of, broader societal involvement. A resilient energy system can deliver the triple win of security and sustainability as well as contribute to climate mitigation targets. It will draw upon indigenous resources, meaning its architecture will be diversified and integrated from the bottom-up, with faults unable to cascade [47]. This has considerable implication for energy system architecture as shown in Figure 2.

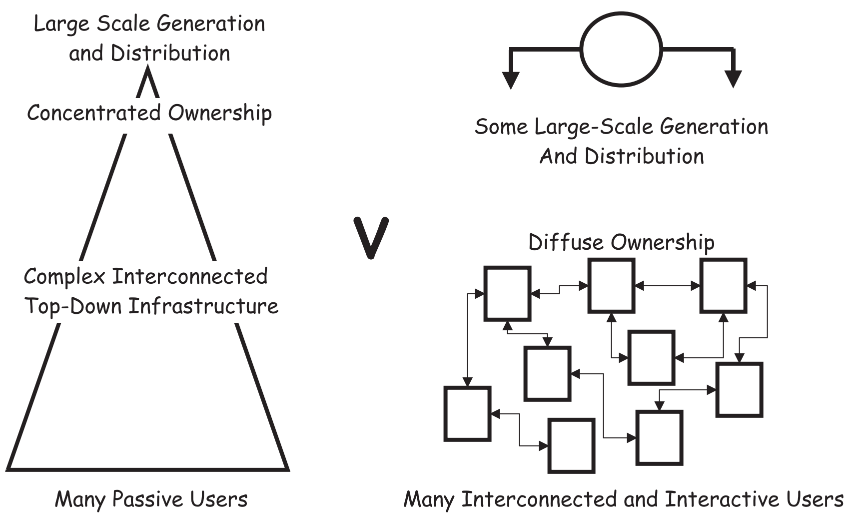

Figure 2. Contrasting Models of Energy System Structure

Realising this in the longer term will require a top-down enabling environment that encourages bottom-up engagement. Driving this changing policy context requires social learning. Photovoltaic arrays connected to the grid by net-metering and solar collectors enable users to minimise charges. But it requires interventions that are targeted at enhancing the adaptive capacity of users. As opposed to being passive consumers, policy should be aimed at encouraging active participation in the energy system. This means learning, in a social context, how to things differently. Social learning is a process of iterative reflection that occurs when experiences, ideas and environments are shared with others [48]. Individuals learn from one another in a variety of methods including concepts such as observational learning, imitation, and modelling. Social learning is a cognitive process. It is not limited to individuals but includes groups, communities and institutions. By creating an enabling framework and genuinely empowering the public we can begin to develop an approach that allows the local to build out to the global in the process of reducing climate change risks as shown in Figure 3.

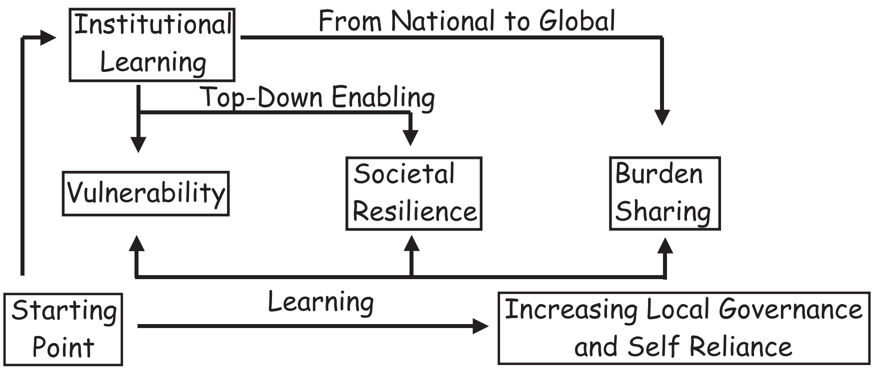

Figure 3. Linking Concepts for Climate Risk Reduction

On the Road to Copenhagen it is important that viable methods for ensuring the widest engagement with the interrelated problems of climate change and energy security are developed. In order to lead the EU needs to show that it can produce a consensus approach that will produce meaningful cuts in emissions as a commitment to burden sharing. Simultaneously it must also show its willingness to make radical shifts – simply tinkering with a few market mechanisms and striking a few bargains is hardly an example of vision and innovation.

CONCLUDING COMMENTS

An Energy policy for Europe is in many ways laudable. Its principle weakness is that it excludes the user from the energy equation. Its narrow focus on top-down interconnection exacerbates vulnerabilities. The EU ETS is aimed at exclusively at the organisational level. Embedding resilience, antidote to vulnerability, requires much broader societal involvement. This will be time consuming, but equally so will developing sufficient nuclear capacity to meet our electrical needs or developing carbon capture and storage technologies that are robust and reliable. There is no silver bullet. But as Einstein remarked we cannot solve our current problems with the same mindset that created them. Small scale bottom-up is not some environmental utopian fantasy but a serious technical, social, economic, and political challenge. A considerable proportion of our energy usage is in the homes we live we in and the building we use. As IEA remarks we need as shift in attitude. In many parts of Europe the public has shown that it is willing to embrace change. The question is whether politicians can shift their myopic focus from gigantism and large scale integration and begin to empower as opposed to impose. Whether or not there is sufficient political will to remains to be seen.

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