Please cite as: Patt, A., Komendantova, N., Battaglini, A., Lilliestam, J. (2011): Regional integration to support full renewable power deployment for Europe by 2050, in: *Environmental Politics*, vol. 20, No.5, pp. 727-742. http://dx.doi.org/10.1080/09644016.2011.608537

Post-print version of the article published in *Environmental Politics* 2011, vol. 20, No. 5, pp. 727-742

Regional integration to support full renewable power deployment for Europe by 2050

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Abstract

The European Union is currently working on a achieving a target of 20% renewable energy by 2020, and has a policy framework in place that relies primarily on individual Member States implementing their own policy instruments for renewable energy support, within a larger context of a tradable quota system. For 2050 the target is likely to be more stringent, given the goal of reducing European carbon dioxide emissions by 80% by then. Preliminary analysis has suggested that achieving the 2020 target through renewable power deployment will be far less expensive and far more reliable if a regional approach is taken, in order to balance intermittent supply, and to take advantage of high renewable potentials off the European mainland. Analysis based on modeling is combined with the results of stakeholder interviews to highlight the key options and governance challenges associated with developing such a regional approach.

Keywords: renewable electricity; energy policy; Supergrid; investment security; security of supply

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Introduction

The development of renewable electricity in Europe is very different depending on where you look and in what perspective. Some countries, like Denmark, Spain and Germany, exhibit strong development. In the past 20 years, Denmark increased its share of renewable power by over 1000%, and Germany increased production by 73 TWh/a between 1990 and 2007. In other countries, like France and Austria, the situation is less positive, as they have experienced decreasing shares of renewables, due to increasing electricity demand. In a European Union (EU) perspective, average annual growth has been a very modest 3.2% in the same period of time (Eurostat 2010). When considered together, EU countries will collectively have failed to meet the Union's non- binding 2010 renewables target (21% of final electricity consumption) by a wide margin (European Commission 2009).

Several support and incentive schemes are in place across Europe. At the EU level, the Climate and Energy Package, finalized in 2009, sets a number of binding targets for the year 2020: a 20% reduction in carbon emissions; a 20% improvement in energy efficiency; and the obtaining of 20% of energy from renewable sources (European Commission 2009). The Emissions Trading Scheme supports this by setting a cap on total carbon emissions from the power sector. The Guarantee of Origin (GO) trading scheme, embedded in the Renewable Energy Directive, creates a legal framework for countries to meet their renewable energy targets through development undertaken elsewhere, either by purchasing excess renewable energy credits from other EU states or by importing electricity of guaranteed renewable origin from non-EU states (Mendonca 2007, Kemfert and Diekmann 2009, Nilsson et al. 2009, Couture and Gagnon 2010). On a national level, the different support schemes are the main tool for promoting renewable power, but there is also a plethora of different incentive schemes at national, regional and local levels. As all effective, and almost all ineffective, support schemes are presently national or smaller scale (res-legal.de 2010), the efficiency of the support can be questioned: by far the largest share of European growth in photovoltaic power (PV) has taken place in Germany, and not in much sunnier southern Europe; 40% of the growth in wind generation has also taken place in Germany, while there is paradoxically much less in much windier countries, like Ireland, the United Kingdom, Norway or France (Czisch 2005, Eurostat 2010).

Looking even further ahead to 2050, there are no official European targets for renewables, but there are indications of what the total greenhouse gas emissions reduction effort will be: 60–80%, in the preambles of the Carbon Capture and Storage and Emissions Trading Scheme Directives (European Parliament 2009a, 2009b); or 80–95%, as recommended by both the Intergovernmental Panel on Climate Change and the European Commission (2010). Emission reductions of 80% or more by 2050 require the power sector to become completely carbon-neutral by then, to compensate for difficulties of decarbonizing other sectors (Battaglini et al. 2010, European Climate Foundation [ECF] 2010).

As renewable electricity is capital intensive, the quality of the production site is the most important determinant of costs; the dependence between costs and site quality (expressed in full-load hours per year) is more or less linear. Supporting PV in the not-so-sunny Czech Republic and wind power in not-so-windy Bavaria may be acceptable if the support scheme is conceived as a market introduction tool with the

aim of supporting technology development, not mainly targeted at electricity production as such. The implementation of feed-in tariffs in some European countries has achieved exactly this: renewable technologies, especially wind, PV and biomass, have been successfully and efficiently introduced in the European market (Foquet and Johansson 2008).

Achieving a 33% share of electricity generated from renewable sources by 2020, and 100% by 2050, is quite different from this. Such targets cannot be considered to be either market introduction or technology support systems. Such high shares aim at producing large amounts of electricity, and then efficiency is a critical component. Inefficiencies that are acceptable on a low penetration level will now be magnified by the scale, and may become unacceptable. Harmonizing support schemes and markets – which is not necessarily the same as merging and uniting these systems – so that all countries in the power system can access the best sites, regardless of national and administrative borders, and exploit these with the best suited technologies may reduce total costs considerably. Below, we will discuss why this is.

Reaching the 2050 target in a reliable and economically sound way: a European–North African Supergrid

Depending on the precise geographical region, the potential supply of renewable electricity can be constraining or not, at least in terms of an integral over time. But electricity suppliers need to be certain that they have enough electricity at any given time at a given place. Hence, they must cope with both the intermittency of the production and the uneven geographical distribution of resources, which is more challenging as the share of renewable power increases relative to fossil fuel-based power. Essentially, this is a challenge of minimizing both the curtailment of generation and the usage of storage (such as with batteries), both of which are expensive (Leonhard 2008, SRU 2010), while guaranteeing an adequate and stable power system at all times. Doing so requires power system planners to think not only of new renewable power plants, but to alter their mindset to include a world of much larger, often international or even intercontinental power grids and markets.

In a recent study, the German Advisory Council on the Environment (SRU) quantified the costs for 100% renewable power in a number of different scenarios. A purely German power system without interconnections to other countries would have an average producer cost of 11.5 €c/kWh, much due to the extensive use of expensive biomass and biogas as dispatchable capacities to smooth the supply-controlled feed-in of wind and PV. In a pan-European, trans-Mediterranean scenario, however, the average cost would be 6.9 €c/kWh on average; fluctuations would be smoothed, and cheap pumped-storage capacities (using excess power to pump water uphill into mountain reservoirs, to generate almost as much power later) would be available in a broader geographical perspective. Against this back-drop, the SRU concluded that ‘an efficient trans-European power grid is a particularly cheap, but politically extraordinarily demanding, option for a completely renewable electricity supply’ (SRU 2010, p. 66; own translation).

This is the setting in which we operate: all further discussion will aim at achieving a 100% renewable power supply for Europe, while coordinating with North Africa. In recent years, the North African countries have defined renewable power targets too,

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of different levels of ambition. Morocco, for example, has a target of 42% renewable power by 2020 (today renewables account for 8% of final electricity consumption). Given the rapid demand increase in the country, this should be seen as a very ambitious target, and it remains to see whether it is actually realistic. At the other extreme is Algeria, with its target of 5% by 2017 and 10% by 2025 (today renewables account for only 0.6%). The current renewable share of final electricity consumption in North Africa as a whole is 9%, of which about 8.5% comes from the Aswan dam in Egypt (Schellekens et al. 2010).

Numerous studies on such a Supergrid power system, often spanning all of Europe and the North African countries on the southern shore of the Mediterranean, have been published in the past few years, all reaching similar conclusions. A European or European–North African Supergrid is technically possible, and one of the cheapest options available to completely decarbonize the power system (for example, Czisch 2005, DLR 2006, ECF 2010, SRU 2010, Zervos et al. 2010). Below, we will explain why such a system is feasible and then discuss some of the political challenges with creating and operating geographically very large power systems.

Demand smoothing

Constructing an efficient grid over vast distances will smooth much of both the high-frequent and the very low-frequent demand variability. The relevant measure is the peak/off-peak ratio, and whereas a small, national power system would have to deal with large peak/off-peak swings, a Supergrid would experience considerably smaller demand swings.

The variability over periods of a day or less is smoothed by the different usage patterns in different parts of the grid. This is partly due to cultural differences – Italians tend to have dinner later than Swedes – but also due to the east–west size of a Supergrid. If it spans several time zones, this will effectively mean a relative time shift of peaks – the 8-o'clock evening news will start at different times across the grid – which reduces the peak/off-peak ratio. In a University of Kassel model for the European Union and Middle East/North Africa, including Eastern Europe and the Urals power system, this demand swing reduction amounts to 11%, comprised of 4% peak reduction and 7% minimum load increase (Czisch 2005). A study commissioned by the ECF found effects of the same magnitude (ECF 2010). As North African demand is still much smaller than in Europe (180 compared with 3300 TWh/a), the demand smoothing effects of a European–North African grid are unclear (Schellekens et al. 2010).

The seasonal smoothing largely originates from different usage patterns on the north–south axis. Electricity consumption in the north is higher in winter, due to increased heating and lighting needs, whereas the demand in the south is higher in the summer, primarily due to extensive usage of cooling systems. In the University of Kassel model, this amounts to a smoothing of only 2% of the seasonal demand variability, whereas the ECF study showed considerably stronger smoothing effects. With increased standards of living in North Africa, an increased use of cooling can be expected, but it is not clear what the effects of this on total system demand smoothing will be.

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Stochastic smoothing of supply

Interconnecting renewable power plants can lead to considerable smoothing of the cumulated supply of the single power plant fleets. Wind and solar power plants are dependent on wind and solar input – that is, the weather – and it can be expected that the supply variability decreases with distance, at least up to distances of the same size as a typical weather system. Numerous studies have addressed this issue for wind; for solar power there has been less quantified study, but similar effects can be expected.

Wind smoothing can be observed in reality already today, following the rule of thumb that larger geographical dispersion leads to a smoothing at lower frequencies. Dispersion over 2 km can lead to smoothing on very short time scales – that is, 55 minutes (Kempton et al. 2010) – whereas interconnection over 800 km can reduce one-hour variability by up to 95% (Katzenstein et al. 2010). The smoothing over larger areas, and longer frequencies, is more disputed. The University of Kassel researchers examined the area between Morocco and the Ural Mountains (5000 km across, or roughly the size of North America). It was found that wind smoothing can reduce seasonal fluctuation by 65%, mainly by increasing the minimum available wind capacity (Czisch 2006). This effect is partly due to the different climate zones – in Northern Europe the windiest months are in winter, while in North Africa they are in summer – meaning that connecting them smoothens much of the seasonal variability (Czisch 2005). In contrast, Kempton et al. (2010), who considered offshore wind power along the eastern United States coast line – that is, within one climate zone – found that the correlation between wind power plant output is indeed very low for distances of 800–1300 km, but there is no additional smoothing by adding more remote power plants.

Power mix smoothing

Whereas stochastic smoothing makes use of reduced correlation between geographically dispersed power plants of the same type, a diverse power mix can make use of low, or sometimes negative, correlations between different recurring weather and climate patterns. For example, the European summer is sunnier than the winter, and cloudy days are more often windy than are sunny days. Wind and sun are to some extent negatively correlated, so that the cumulated output of a wind-solar power plant fleet can be expected to have a more stable output than that of a one-technology fleet. A more diverse power mix will thus be less impacted by adverse weather. Still, extreme events like storms may effectively halt both solar (no sun) and wind (too much wind) power generation across a large area. In such cases, the power supply in affected areas has to rely on transmission from outside. This is another strong argument for grid expansion.

A European–North African Supergrid would make use of the seasonal anti-cyclic wind (winter maximum) and sun (summer maximum) supply patterns, for several reasons. First, the wind patters in Europe and North Africa show a negative correlation, such that when it is calm in one region it is typically windy in the other. Second, the seasonal pattern of European wind power is negatively correlated with solar production from Spain and North Africa. To illustrate, northern Europe and

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Spain can generate about 40% as much wind power in July as they can in January. However, solar production in Spain and North Africa is two and a half times higher – the inverse of 40% – in July compared with January (Czisch 2005). Through a sensible combination of wind and sun, a more efficient seasonal smoothing of supply can be achieved. This can be clearly seen in the ECF study, which examined an 80% renewables scenario for 2050. Although the peak wind power supply in winter is twice as high as the minimum supply in summer, the cumulated supply from solar and wind power is relatively constant over the year, at 35–40% of total electricity supply (ECF 2010).

Site access

Renewable electricity assets are capital intensive with very low variable costs. This makes the quality of the production site – the windiness, or the insolation – the most important variable for the siting decision. In theory, the yearly average potential may be sufficient for 100% renewable power in Europe, as the supply potential and the demand are of similar magnitude. In practice, however, Europe would need to utilize all sites, including the marginal, less windy or sunny sites, where the return on capital investment is lower. Including the vast potential of North Africa would not only increase the potential by two orders of magnitude, thus allowing cherry-picking of sites and a consequent lowering of total costs (Battaglini et al. 2009), it would also include much better solar sites than are available in Europe. For example, the global horizontal irradiance (the main variable for PV siting) is around two-thirds higher in North Africa than in Germany, the world leader in installed PV capacity. The average direct normal insolation (the main variable for CSP) is 15–25% higher in North Africa than in Spain, Italy and Greece, and has considerably less seasonal variability (DLR 2005, 2006). With all other factors constant, North African levelized PV costs will be roughly one-third of the cost in Germany, while the levelized CSP cost will be about 15–25% cheaper than in southern Europe. (It is not economically feasible to operate a CSP power plant in northern Europe, due to frequent cloud cover.)

Even more importantly, the possibility of CSP production in North Africa and, to a lesser but still significant extent in Southern Europe, adds another dispatchable renewable power source to the mix. Producers are beginning to equip CSP power plants with units to store heat; for example, as high-temperature molten salt. These fill with excess heat during daytime, and can then produce power overnight and during periods without sun. Accordingly, analysts increasingly view CSP as a 'baseload technology' (for example, Club of Rome 2008, Trieb et al. 2009), which can assume the critical role of balancing other intermittent power sources, thereby reducing the need for expensive electricity storage, and reducing the pressure on the hydro-electric dams in Scandinavia and the Alps to handle the system balancing.

In these technical matters, there remain a number of unknowns or points of dispute. Analysts do not know exactly how much storage will be needed, or what kind of storage is the most appropriate. They also do not know what role other load management approaches can or should play in the future. Such options include pricing power differently throughout the day, or by using 'virtual power plants', where a single power provider guarantees a flow of power into the grid, but that flow may come from a number of different generating options. There is a consensus emerging,

however, that a Supergrid offers the possibility to manage large portions of the fluctuating supply in a very cost-effective way. The literature cited in this and the previous sections is congruent in that it clearly proposes a Supergrid as the cheapest way to handle intermittency. Still, unifying European electricity policies and markets, and triggering the necessary amount of investment, especially in North Africa, is a daunting task with caveats and obstacles of a magnitude that could potentially make the entire vision remain a vision. We move to discuss some of the more serious caveats and obstacles.

Perceptions, challenges, and risks of a Supergrid connecting Europe and North Africa

Moving from the technical to the political level, there are three fundamental types of concerns associated with a Supergrid connecting Europe and North Africa. The first of these concerns the benefits that North African countries and citizens can and will receive from it, and whether these are compatible with the benefits that Europeans hope to receive; this would form the backdrop for any political deal. The second is associated with building it, and overcoming the obstacles to securing the required amount of investment. The third is associated with maintaining it, and ensuring that it can supply power in a reliable way. We describe each in turn.

A deal with North Africa

Any future system of intercontinental renewable electricity trade requires clear and stable deals between European and North African countries and/or companies (Patt 2010). However attractive such deals seem from a technical perspective, there is a significant caveat. Today, there is no clear understanding of what North African countries – their governments, power companies, and citizens – expect, wish, or need from such a deal, or if they are willing to let Europe use North African land for its power supply. Some authors have assumed that what North Africa needs and wants is electricity to satisfy the rapidly increasing demand, and desalinated water to reduce pressure on fossil aquifers (DLR 2007, Club of Rome 2008). To our knowledge, however, no systematic analysis of this assumed demand has been performed.

A number of political (the Barcelona Process and the Mediterranean Solar Plan), private sector (the Desertec Industrial Initiative), and research-oriented studies (led by the International Institute for Applied Systems Analysis [IIASA] and the Potsdam Institute for Climate Impact Research [PIK], and by the University of Giessen) have since 2010 begun to organize workshops and stakeholder surveys, some involving high-level political actors, on this issue. These studies may begin to provide robust insights by 2011. Anecdotal evidence from them suggests that the most important expectation from North African countries is of large-scale job creation, mainly in manufacturing and operating the power stations on their soil. This is one of the largest problems in North Africa, which has one of the lowest employment-to-population ratios in the world: only 45% of the population of active age is employed, and of these 42% are working poor, earning less than $2 a day. The total North African unemployment rate increased by 25% between 1997 and 2007 and is now the second largest in the world (International Labor Organization 2009).

It is not clear whether expectations of large job creation are realistic. The estimates for the entire CSP sector go up to two million people employed globally by 2050 (DLR 2005, Richter et al. 2009). The European Solar Thermal Electricity Association (ESTELA) estimated that the deployment of 20 GW of CSP capacity by 2020 – the target of the Mediterranean Solar Plan – could lead to the creation of 235,000 job years. Of these, ESTELA estimated 40,000 to be in manufacturing of components, 120,000 in construction, and 35,000 in operation and management (ESTELA 2009). But the method by which ESTELA generated these estimates is not transparent. Preliminary work at the IIASA, which modified an employment model generated by the United States National Renewable Energy Laboratory to take into account North African labor costs, showed much more modest job creation. In the IIASA work, the same 20 GW of capacity would generate up to 120,000 job years, and then only if all components were manufactured in the region (which is not likely to be realistic), and taking into account indirect employment effects. Given that the North African countries are home to 150 million people, and projections indicate an increase to 250 million by 2050 (DLR 2005), this level of job creation would be welcome, but would not, on its own, make an important contribution to the reduction of unemployment.

Attracting risk averse investors

Even with a stable international or bilateral deal, investment in CSP in North Africa may still not take place because investors perceive renewable energy projects in the region as too risky. Several studies have shown that such risk aversion plays an important role in energy markets by delaying a certain type of technology. For example, banks have in the past in many countries been unwilling to provide financing for renewable energy projects, which they regarded as being too risky (Arrow 1985, Coenraads et al. 2006). It has also been shown that attracting finance is much easier, and the conditions better, when market instruments to reduce risks connected with renewable energy projects, such as feed-in tariffs, have been available (Mendonca 2007, Couture and Gagnon 2010). Risk-averse behavior not only leads to a situation in which fewer projects and less capacity are realized; in cases where perceived risk is high, but acceptable, investors require higher risk premiums and thus higher returns on projects. Recent research at the IIASA and the PIK has addressed the perceptions of such financial risks of North African CSP investments both in a stakeholder interview and questionnaire process, and the cost impacts of it in a modeling approach.

The interviews identified complex and corrupt bureaucratic procedures as the main problem, both with regard to its high probability and its high impact. This creates a situation where investments do not happen at all, as lengthy and unpredictable permission processes make investments unattractive. Instead, investments happen in other areas and regions where conditions are better, or in other types of projects. The stability of political regimes was also seen as an important obstacle, adding to the uncertainty of renewable energy projects. Interestingly, and in contrast to what European media reports, only two interviewees saw force majeure (including terrorism) as a serious concern, but all agreed that such events are not very likely (Komendantova et al. in press). Other risk categories, such as environmental and general financial risks, were perceived as low-impact and low-probability. In general, the findings show strong agreement between the perceived likelihood to happen and

seriousness of concern, reflecting a propensity to conflate likelihood and magnitude (Patt 2007).

The identified risks not only reduce the growth rates by deterring investors, but also make the realized projects more expensive. The increased risk premiums are reflected in increased rates of return, effectively making the same renewable energy project more expensive. Based on this, IIASA and PIK researchers modeled the impact, or the cost increase, of the perceived investment risks using the MARGE generation cost estimator framework. With this model, Williges et al. (2010) showed that the total subsidy costs for driving CSP through the learning curve and making it competitive with coal could cost European tax payers subsidies in the order of magnitude of €20–40 billion over 20 years, a conclusion consistent with other results (Ummel and Wheeler 2008, Williges et al. 2010). Changing the internal rate of return, thus simulating a change in perceived risk level and consequently risk premium, showed a dramatic effect. When the internal rate of return moved from 5% (a low-risk public–private partnership project) to 20% (a pioneer project that, in the absence of a track record, the bank perceives as high risk), the total amount of subsidies required to scale CSP up to be competitive with coal jumped from €15 billion to €329 billion.

Measures aimed at reducing perceived risk will thus reduce the total investment needed to make CSP competitive with conventional generation technologies. As investors see regulatory risks, including corruption and inefficient bureaucracies, as the most serious and risks, this is a task that falls entirely on policy-makers. It is possible to treat such kinds of risks, and this does not imply any significant government expenditures.

There are already different programs conducted by international organizations, non-governmental organizations and the European Commission like the Mediterranean partnerships programs, which are part of the Barcelona process, the Extractive Industries Transparency Initiative and other programs aiming to improve regulatory climate in North Africa conducted by the United Nations Development Programme. Succeeding in these programs will not only facilitate an expansion of renewable power in North Africa, but also decrease electricity costs for consumers by several cents per kWh, all in all, savings in the order of magnitude of hundreds of billions of Euros are possible without increasing government spending. In short: reducing risks is a win–win situation.

Security of supply

There is considerable suspicion among many European decision-makers about the reliability of the North African countries as electricity suppliers. One observer writes about Desertec – a private-sector initiative to link the European and North African markets – and asks ‘Why create a new hostage to fortune?’, concluding that ‘the stage is set to recreate an uncomfortable parallel with western dependency on oil from Saudi Arabia, Iran and Iraq’ (Pearce 2009). The former CEO of Vattenfall, Lars Josefsson, adds that ‘Europe must source its power from Europe’, otherwise its supply will be threatened by unstable and unreliable governments (Lubbadeh 2009, Zeller 2009). The question of security of supply is indeed of great importance: if the electricity supply is not secure, the Supergrid approach to decarbonizing the power sector will not work.

This concern can only be partially explained by the track record of European–North African energy trade. Algeria and Libya are important suppliers of gas and oil to Europe, and have been so for a long time. Algeria's supply to the EU has been constant and has not been seriously interrupted due to political conflicts during the past 30 years. During the second oil crisis in 1980, Algeria unilaterally increased the gas price to France and withheld parts of the supply for two years, until the crisis was settled and the gas price was linked to the oil price. At the time, Algeria's reliability as a supplier was questioned, but it was also concluded that 'Algeria's increasing reliance on gas exports [. . .] may engender greater caution in the manipulation of gas exports' (Adamson 1985, p. 20). Since then, Algerian exports to Europe have been stable. During the Libyan–Swiss political conflict about the arrest of Hannibal Ghaddaffi in 2008, Libyan oil exports to Switzerland were cancelled, but resumed after two days. In March 2010, Libya declared a 'holy war' and a total embargo against Switzerland, a move that led to much media attention, but not to any significant economic effects or to oil shortages in Switzerland (RIA Novosti 2008, Windfuhr and Zand 2010).

Assessing security of electricity supply in a Supergrid scenario is difficult. Today, there are no robust tools to assess the security of electricity supply in a holistic scenario approach. There are, however, studies that look at different aspects of energy security, also for a Supergrid scenario. The reasons for investigating a Supergrid in the first place are economic – it will be cheaper to use only the best production sites – but also based on a security argumentation: the large grid will reduce the risks of intermittency and increase system stability (see above). This leaves the political risks, which need to be somehow assessed. Most existing approaches to energy security focus on diversity in oil and gas supply (see Lefe` vre 2010, Stirling 2010), which are inherently different from electricity, as they are storable, partially substitutable (with each other) and, in the case of oil, traded on a liquid world market. The idea behind this diversity approach is that 'a highly import-dependent system that is well diversified, need not necessarily be a risky one' (Bhattacharyya 2009, p, 2412), as the system can absorb the failure of the largest supplier. However, an import-dependent system that is only slightly diversified, but based on supply from reliable partners is not a risky one, whereas a diversified system in which the suppliers unexpectedly form a cartel may be much more insecure. Thus, a diversity approach is a frequently used, but rather blunt instrument to assess political risks of energy imports.

So far, two studies have investigated the issue of political risks to European power system stability in a Supergrid Europe/North Africa in depth. Both of these studies conclude that the concerns are largely unfounded and the risks are relatively small, although they exist.

In the first study, Lacher and Kumetat (2011) investigate both the risks of terrorism and of intentional supply cuts – the 'energy weapon' – in a Supergrid scenario. They conclude that terrorist attacks against the power system 'cannot be dismissed entirely', but that, if such attacks happen, the effects are likely to be very limited due to the interconnectedness of the system, the complexity of a large-scale attack, and the fact that any blackouts are likely to be short-lived (Lacher and Kumetat 2011, p. 10). They find that vulnerability to terrorism is not likely to be higher than the current vulnerability due to Europe's imports of gas and oil from the region. The track record of terrorism against power installations shows that the risks have been small in the

past. The United States national counterterrorism center database registered 2212 terrorist events against energy installations worldwide – around 2% of all registered terrorist attacks – between January 2004 and March 2011. Of these 76 attacks – about 3% of the total – affected electricity installations. Four of these events impacting the electricity sector took place in Europe and two attacks took place in Algeria, whereas more than 70% of all attacks took place in Colombia, Iraq or Pakistan (WITS 2011). Most attacks against power systems – more than 60% – were aimed at transmission facilities, because these are the least protected parts and the effects of disabling them are likely to be higher than attacks against other parts of the system (Tranchita et al. 2009, Toft et al. 2010); similar data have been reported also for the period 1984–1999[1] (Greenberg et al. 2007). Toft et al. (2010, p. 4419) explain this low frequency of attacks upon power systems in terms of the limited incentives terrorists have to attack such facilities: 'threatening this type of target is not highly intimidating, it is rarely a strong messenger of ideological symbolism and [. . .] it requires some skill and knowledge to destroy them'.

Lacher and Kumetat (2011) also conclude that European fears of intentional disruptions to future electricity deliveries are based on false analogies to the trouble experienced with Russian gas, as renewable electricity trade with North Africa will have completely different technical and geopolitical characteristics. As electricity is a perishable, non-storable good whereas gas and oil are storable goods, the economic interdependence between Europe and North Africa will be stronger for electricity than for fossil fuels, and this interdependence will be a strong deterrent to any politically motivated disturbances. Similar conclusions are reached by Taylor and van Doren, who argue that this interdependence is also high in the oil import case: 'Catastrophic supply disruptions would harm producers more than consumers, which is why they are extremely unlikely' (Taylor and van Doren 2008, p. 7).

In the second study, Lilliestam and Ellenbeck (2011) investigate this argument quantitatively and in detail, and argue that most countries refrain from acts that may be considered aggressive, unless they are given a reason and the possibility to create a credible threat to force its will on a trading partner. As electricity cannot economically be stored on a large scale, all electricity that is not sold at one instant in time is lost and a supply disruption would cause a continuous loss of revenue in the exporter country. In the importer country, however, the costs of a large and sudden import disruption would be initially high (caused by blackouts) but then decrease to almost zero as system stability is restored by other, geographically dispersed backup capacity, which must be in place to maintain a high level of operation security in a renewable power system. Lilliestam and Ellenbeck show that, in the Desertec scenario, the export revenue losses are likely to be higher than the importer's blackout costs. Hence, they conclude that 'energy weapon' events are unlikely, as the exporters would be unable to produce a credible threat: they would have no leverage and thus very bleak chances of intimidating Europe. Hence, they are unlikely to try to extort Europe using future electricity deliveries. Europe will only be vulnerable to extortion in the case where all North African countries coordinate action and embargo Europe together, and even this vulnerability can be mitigated by either increasing European reserves or by importing less electricity than foreseen in the Desertec scenario (Lilliestam and Ellenbeck 2011). In a rough estimation, Schellekens et al. (2010) quantify these costs, for a three-week, 25 GW disruption of exports from North Africa

to Europe, to 0.3% of current European GDP and the lost income to 50% of current Tunisian GDP, or 10% of current Egyptian GDP.

Other, non-quantifiable costs like reputational damage may be prohibitively high and apply highly asymmetrically: such costs only apply to the actor who breaks the deal – in this case, the exporter – which makes a sudden, one-sided supply cancellation even more unlikely. Europe will thus have little to fear in terms of politically motivated supply disruptions: a North African country would have nothing to gain and much to lose. In contrast to the prevailing view in the European media, these results show that Europe will not be dependent on North Africa, it will be the other way around. In fact, North Africa may become dependent on the income from the electricity exports to Europe, and they may want to consider whether this risk is acceptable to them or not.

Conclusions

There are significant benefits of connecting Europe into one single, fine-meshed and long-distance power grid, and even larger benefits may arise if North Africa is included in this system. The benefits originate from supply and demand smoothing effects that only arise in a very large power system, and from accessing the best production sites for renewable electricity generation. A Supergrid makes it technically easier, at lower cost, to achieve very high rates of renewable power penetration.

Creating such a European–North African Supergrid system is, however, a political challenge of high magnitude. Today, we do not know what the North African countries expect or wish from a deal with Europe – whether they would be comfortable with European-financed renewable energy developments on their territory – nor do we know what Europe expects from North Africa and what it is willing to give to be allowed to use North African land for its power supply. Recent research has shown that the perception of risks of investing in renewable power in North Africa is presently high; bureaucratic difficulties and corruption are perceived as particularly problematic. This not only deters investors from investing, it also makes the projects that are indeed realized more expensive. Reducing the investment risks may save hundreds of billions of Euros for consumers and government budgets.

The idea of a European–North African Supergrid often provokes concerns about European security of supply, particularly given the unpredictable behavior of Libya in recent years. No commonly accepted method of assessing security of electricity supply exists today, but novel assessment frameworks indicate that the European power supply is unlikely to be interrupted due to political reasons, as North Africans would have nothing to gain and much to lose by cutting exports. On the contrary: Europe would not be very vulnerable, but the North African exporters would be strongly dependent on the income from the electricity trade with Europe.

Note

1. The cited data concern the United States during 1984–1999: here, 3% of all electricity system disturbances were attributed to ‘sabotage or vandalism’; 59% of these disturbances affected transmission lines and towers.

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