THE SUPER-GRID

A CONVERSATION WITH GREGOR CZISCH BY ALESSANDRO COLOMBO

Dr Gregor Czisch, a fully qualified agriculturist, studied physics at Munich Technical University, specializing in energy supply. He wrote his PhD in electrical engineering on scenarios for a future electricity supply with renewable energies. He has worked on various topics in the energy-related field at Munich TU, the DLR Stuttgart, the Fraunhofer ISE in Freiburg, and the Max Planck Institute for Plasma Physics (IPP) in Garching. Among his key areas of scientific focus were solar building engineering, utilization of biomass, wind energy and hydropower, primary energy analyses, emission analyses, high temperature heat storage and solar thermal power plants. During his work in the R&D division Information and Energy Economy at the Institute for Solar Energy Supply Techniques (ISET) and at the Institute for Electrical Energy Technology/Rational Energy Conversion (IEE-RE) at the University of Kassel, he worked on potential-analyses for renewable energies and on simulating their production behavior, on conceptualizing energy transport systems and on developing scenarios for a CO2-neutral electricity supply. This work resulted, among other things, in a PhD with the title Scenarios for a Future Electricity Supply – Cost-Optimized Approaches to Supplying Europe and its Neighbors with Electricity from Renewable Energies, *for which he was awarded the distinction summa cum laude. Since completing his doctorate, parallel to his research at the University of Kassel, Dr Czisch has worked as a consultant to the Scientific Advisory Council on Environmental Change of the German Federal Government (WBGU) and was, among other things, invited as an expert to hearings in various ministries, parliaments and utilities.*

→I ON FOCUS

"It is a good morning exercise for a research scientist to discard a pet hypothesis every day before breakfast."

KONRAD LORENZ

YOUR STUDIES DEMONSTRATE THE FEASIBILITY OF A European electrical system supplied only by renewable sources. What are the main points of your proposal?

My proposal – derived from the results of my research – is to develop a large scale grid throughout Europe and Sahara – called *super-grid* – to interconnect wide spread different sites with electrical generators supplied by renewable sources, namely wind, solar, hydropower, and biomass.

In contrast with the *smart grids*, which represent a futuristic approach made of highly intelligent applications, the super-grid is already feasible with the technology available today, and serves to exploit in an optimal way the enormous potential of the renewable sources. [PICTURE 1].

To demonstrate this possibility, I carried out from 1997 till 2004 a technical and economical systemic study. The first preliminary publication was in 2001. I analyzed the potential and the temporal behavior of the renewable sources in all different locations worldwide and the corresponding unitary cost of the equipment for production and transmission of renewable electricity including all costs for operation and maintenance. The data for Europe and its neighborhood were then fed in a huge mathematical optimization to calculate the optimal distribution and dispatch of all generators and transmission systems.

The main result for the base case scenario – only allowing to use existing technologies at current market prices (around 2001) – is that the most efficient arrangement is a system where *two thirds of the electrical supply are provided by wind power*, which is available in all areas but with different daily and seasonal behaviors (e.g. in Northern Europe the strongest winds are in winter, while in Sahara in summer). The super-grid indeed compensates the fluctuations of electricity produced in different countries and therefore is foreseen – as a result of the optimization – to strongly interconnect the sites of production and consumption.

The other sources selected to provide a mayor contribution are biomass (17%) and already existing hydropower plants (15%). Biomass and existing storage hydropower (not pump storage which only provides a minor contribution as backup) are mainly used as energy storage (the most important storage hydropower is existing in Scandinavian countries) and as backup when the production from wind power is not sufficient to meet the demand.

The role of the solar power from solar thermal power plants would be instead only marginal (1,6%), because the present technology to exploit the sun is very expensive compared to the other ones. In fact the cost figures for the solar thermal power plants in the scenarios might have been a bit optimistic. They have not been based on current market data since there was no new plant built for more than a decade. The first new commercial one was built in 2008 and the costs were twice as high as estimated for the base case scenario. Therefore it is unlikely that the optimization would have chosen solar thermal power plants if it would have "known" the real today's costs.

Photovoltaic (PV) production is not selected by the optimization. To give a significant contribution, the cost of the PV installations should be reduced by 8 times compared to the costs figures of around 2001 or about 5 to 6 times compared to the today's costs. Then the optimization finds a best solution that includes 4% of the electricity produced by PV applications only sited in the sunniest Sahara states. But this cost decline might be unrealistic. So even this small contribution might eventually never become part of a cost optimal solution.

The overall cost of electricity calculated for the base case scenario is 4.6 Euro cent/kWh. This can be compared to the 6-10 cents/kWh we are paying at the electricity market (EEX) for consumption shaped electricity today. This outcome is very encouraging: with a proper mix of renewable energies and a super-grid infrastructure embracing Europe, North Africa and smaller parts of Siberia, we can provide electricity to all countries at a lower cost than today, freeing the system from fossil or nuclear fuels and with no more substantial impact on the environment.

Isn't the sun power more available than wind in Sahara?

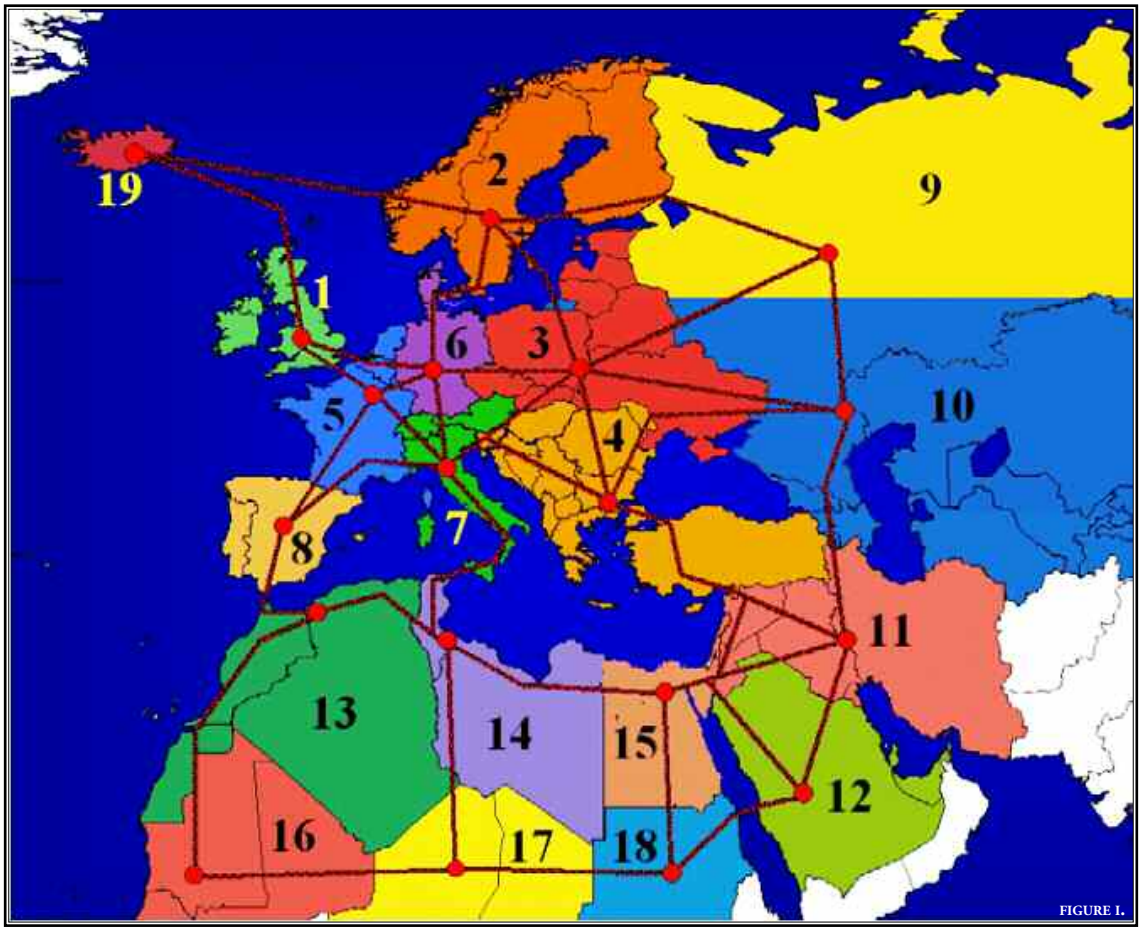

FIGURE I.

Yes and no, the wind resources are tremendous in North Africa. I agree that in the common perception the Saharan region is normally associated with the sun resource, but at a closer look also the potential of wind energy is enormous. According to a recent study from the Harvard University, and confirmed by several others also my some years older studies, eight countries in the Sahara could individually generate the whole electricity need of Europe or some times more from wind power. Hereby no site is selected where the average load of the windmill was less than 20% of the rated power. Many sites are much better. So the potentials could serve with more than enough amount cheap electricity.

On the other side, the nuclear energy seems to be even cheaper, at 2 cents per kWh, according to its supporters. Is that realistic?

The figures for the nuclear energy are under serious debate. The nuclear power stations need a huge investment for their construction and a long working time for their amortization. This creates the need to run the plants continuously at full power, "until it breaks into pieces", and only then the average cost of the generated electricity can decrease more or less to the variable costs of 1.5-2 c/kWh if we neglect the debate about the costs of insurance and the long term cost of nuclear waste disposal.

Nuclear plants are therefore used to mainly cover the steady base of the demand of electricity. But if the use of alternative sources like wind power expands also a growing part of the base load band will be provided by them, the nuclear plants would no longer be run continuously, the initial investment is recovered more slowly, and the average production cost increases.

In other words, nuclear plants are more or less incompatible with an increasing quota of renewable generation. An intelligent strategy of investment should privilege instead other flexible and adjustable types of generation, which can perfectly work with the variability of alternative sources. The existing nuclear stations should be gradually phased out and no new ones should be built.

How was the reaction from the scientific community and the political level to your proposal?

After almost nine years from the first publication of the results and a large number of presentations in conferences and papers, I consider the reaction too cold and too slow.

This has to do with the political positions, and the interests involved. In Germany for example we have three main strategic directions with regard to the energy issues.

First, the coal lobby, which is strong both in the right and the left-wing parties like the SPD, and promotes the construction of new coal power plants more or less ignoring the climate impact.

Secondly, we have the supporters of nuclear power, equally strong and well connected to the utilities and also with some background in different parties.

At last, there are the opponents of both of them, which can be identified in the "green groups" across the several parties. They often promote a vision of "beautiful" small-scale installations, a sort of decentralized autarchic model, and are supported by manufacturers and installers as the ones of solar panels.

Such an approach, even if perceived as alternative to the traditional system, can never really compete with or hardly replace the big nuclear or coal industry, and therefore allows for their long-term permanence.

Decentralists oppose even the construction of new power lines, which are also needed to transport energy from wind power within the national borders.

They think of an ideal like every house supplied by its own solar cells and independent from the network, but that in the best case leads to very expensive supply with poor energetic efficiency.

Who are the parties supporting your scenario?

My proposal received strong support throughout most political parties, either officially or indirectly. I have been invited to many hearings, like at the German ministry of Economy, to discuss the law for the acceleration of the construction of transmission lines *[Energieleitungs-ausbaugesetz]*, as well as in the EU parliament, where I presented my results firstly in 2004, or in conjunction with the Baltic sea parliamentarian conference, leading to a resolution for the construction of HVDC lines (High Voltage Direct Current, an old and modern technology used to transmit electricity to very long distances, above 800 km). In 2009 a new EU directive was issued, to allow the import of electricity generated from renewable sources from non-EU countries, in order to arrive at the aimed quota of 20% of the EU energy consumption provided from renewables by 2020.

These regulations are consistent with the Supergrid idea.

Also the industry is now drawing attention to the super-grid thanks to the Desertec Industrial Initiative, joined by major energy groups like RWE and EON. I initiated this idea since I contacted the main driver the Munich RE in 2005. Now the result is – a bit different than I tried to communicate – based on large solar thermal installations in the Sahara Desert, with the electricity transported to Europe by HVDC lines. So again we see parts of the super-grid.

Unfortunately the solar thermal technology is not mature enough, it is still expensive in comparison to wind power (15-20 c/kWh against 3-5 c/kWh for wind energy) and would take too long time to develop to a major source able to help to avoid the worst effects of the climate change in time.

In 2008 we have had only 100 MW of new solar thermal plants, while the new wind generators amounted at 27.000 MW in the same period, almost 300 times more, and growing constantly by 30-40% per year.

I don't know why Desertec Initiative focues on solar plants, but a guess is that they don't really foster a quick transition to alternative sources, since they represent the industrial groups and utilities that also run the existing traditional plants.

Do you see geopolitical issues that might render instable such realization?

I answer with a question. Why don't we raise a geopolitical concern to the fact that Europe currently imports about 25% of its natural gas imports from a single country, Algeria, and another 40% from one other single country, Russia? The gas pipelines currently in use act exactly like a supergrid, transporting gas from Sahara and from Siberia to Europe. There is no conceptual difference from transmitting electricity instead of gas.

The only difference is that the gas is stored in big storages to guarantee about 2 month of autonomy (The storage hydropower storages with a capacity roughly equal one month of the electricity consumption are somewhat smaller), but if Algeria would stop the supply we would soon have big problems. And we experienced a crisis when Ukraine stopped the transit of gas from Russia through its territory.

The scenario with renewable electricity would be instead much more secure, because the sources can be diversified, with less dependency from single countries.

Think about the enormous rise of the oil price, which increased ten times in a decade, jumping from roughly 10$/barrel in the 90s to the 150$/barrel we saw recently… this cannot happen with renewable sources, which instead become cheaper with time, thanks to the advancement of technology, and are available more or less everywhere, with a relatively low variation of cost.

What conditions would facilitate the implementation of a new grid? How are you involved in fostering that idea?

One approach is to apply the EU directive and the German law mentioned before, which facilitates the erection of new transmission lines, but we lack a similar legislation all over Europe. We further need a harmonized regulation to support the financing of these projects, for example a common European feed-in tariff able to cover the cost for production and transmission of the electricity.

This would be a powerful instrument to attract investors and to guarantee a certain security of the financial returns, which in turn would give access to cheaper credits. I'm lobbying for that idea since several years, lately in the "Mitigation Country Study for Germany" for the UN Human Development Report 2007/2008 *Fighting climate change: Human solidarity in a divided world.*

What consequences may this large grid system have on the Saharan countries?

The benefits for the concerned countries in Africa could be tremendous.

I give one simple example. To import 10% of its electricity demand from wind energy in Morocco, Europe would have to invest about 3% of its GDP in wind generators in Morocco. This corresponds to roughly 200% of the Moroccan GDP. Such a decision would boost the local economy, creating jobs, local competences and industries. In addition it would help Morocco to produce its electricity from its own wind resources since the resources can more cost efficiently be used in large scale than for the small national demand. The tremendous potential can hardly be exploited to a considerable extend if there is not a powerful connection with an inter-regional grid with the big consumer Europe.

Such a large-scale cooperation based on renewable energies would constitute a win-win situation, and the same is valid for several other Saharan countries.

It would be a clear sign towards a systematical change in the way we live together, because it would not be a fragmented intervention or a temporary help for a developing country, but a sustainable investment in order to serve for a mutual interest in the long term.

Before we go on with a more divided world, more tensions throughout the Mediterranean, more immigration phenomena, we have to think of cooperation and catch such an opportunity for a global human development. It reflects an important decision we have to take, to find a standpoint cooperation or separation.

Is there any feedback from the Saharan countries?

Yes and very positive. Since the beginning of my work I've been cooperating with politicians and scientist from Morocco and from other North African countries, like the former Minister of Mining in Algeria who published the results of my study in his journal, or Egyptian authorities, or Sahara-wind a company lobbying for exports of wind energy from Morocco for roughly one decade now. Many Africans have well understood the benefits of such a system.

Are there similar projects outside Europe and Sahara? Nobody has developed so far a systemic study like mine for another world region.

A study with some similarities but much simpler was published in Scientific American. I had exchanged ideas with the authors in some conference in 2004, but they followed a more simplified approach and did not optimize the whole system.

I have discussed the results of my research also in China and India – here in connection with the Observer Research Foundation – and I saw some further developments.

An interesting development in Africa is driven by the enormous hydropower potential located close to Inga at the river Congo. Here could be built one single hydropower station that could deliver about two thirds of the whole African electricity demand at very low cost, around 1 c/kWh. This opportunity is known since decades. And there are other very good sites at the river Congo and at other African rivers.

Several African countries are joining together to build up so called power pools. The Idea is to erect a kind of pan African Super-grid to make use of this potential source of electricity at Inga all over Africa. There is some involvement of The World Bank, the African Development Bank, and industries like ABB. This development could be combined with the development of the European/North African Super-grid.

In 1989 Karl-Werner Kanngießer, an expert at HVDC, proposed that a part of the electricity from

Inga could be delivered to Europe by means of an HVDC connection.

I knew this proposal and therefore I also elaborated one scenario making use of the energy from Inga, with the interesting result that the overall cost of electricity would be reduced considerably, both because the hydropower is cheaper in itself and because it helps to restrict the remaining use of wind power to better sites with higher efficiency, an advantageous systemic effect.

I am discussing this scenario and the combination of the two Super-grids with African experts. We also consider potential problems of security when a huge proportion of electricity comes from one single site. Or we look at the situation where at once a huge part of the production comes from a new plant and would force existing plants to be switch off, a situation which is not very welcome by the owners of the existing plants. But combining the African Super-grid with the European/North African Super-grid both problems could be solved since the relative contribution of the Inga power plant would be much smaller in the common system and the backup capacities for emergency situations would be much bigger.

So the combined Super-grid system expanding from Inga over the whole African continent and to Europe matches very well with the European and African demand and the need of African development. If we imagine the routes connecting Inga with Europe, we could feed electricity along the way in many grids of African countries, supporting industrialization and development at very low cost. When the African demand grows further African renewable sources like wind, hydropower or biomass could be used to feed into the Super-grid while the more expensive electricity could be used and paid by the rich European countries.

How is public awareness about the energy debate? Is it still considered a merely technical issue?

My feeling is that the public awareness is growing quickly. I am asked to give presentations in many different contexts, technical, political, or groups of interested citizens, and all of them are very open minded – as long as they do not belong to a certain lobby or a company's shareholders or belief in a very decentralistic approach.

However, the opportunities represented by the super-grid are not yet fully arrived at the political level. If we look at the recent Copenhagen debates: instead of developing new ideas, they are still discussing about the trading of CO2 emissions, carbon limits, carbon-taxes and other old-style proposals which hardly are effective because they are too much based on the unrealistic believe in the positive market forces and neglect the inelastic behavior of the consumers in the case of energy consumption.

The carbon tax for example cannot achieve any significant CO2 reduction, because Energy is a good with low *price elasticity*: when the price increases, the consumption remains the same (like the mentioned 10-time increase of oil price which had hardly any effect on the consumption). Another tax on the fossil fuels will not really help to reach any goal of reduction, but will only make the energy more expensive, resulting in harmful social effects like reduced accessibility for poor people. In the rich state Germany, as many as about 800.000 households are disconnected from electricity and/or gas supply annually because they simply cannot pay the bill. This has serious consequences not only for the lifestyle but also for health.

A tax intervention on energy reflects an old political mentality based on the believe that the marked will be the best regulation.

If governments want to change something they have to think in completely other ways. E.g. they should directly change the electricity system, which is responsible for roughly half of the global CO2 emissions from fossil fuels. Our society has the possibility to establish a cheaper electrical supply without CO2 emissions. Why aren't these solutions taken into account in the climate debate? There is not enough political awareness about the known possibilities. ▣