Till Stenzel assesses exports of solar energy from North Africa

There is no doubt today that solar electricity export from the deserts of Northern Africa to Europe is technically feasible. While it is clear that such 'Desertec' projects are technically, institutionally and financially complex, the picture that emerges after piecing together the individual pieces of this jigsaw is one of utilising proven components and technology to serve a mature market with a clear need for increased supply of electricity from carbon-free sources. Recent initiatives such as the German-led 'Desertec Industrial Initiative' (DII) and the World Bank's $750m Clean Technology Fund (CTF) programme for scaling-up concentrating solar power (CSP) technology in the Middle-East/North Africa (MENA) region merely serve to highlight that industry and policy-makers have increasingly realised its overwhelming potential.

What Technology can deliver Today...

What are the individual components of such export projects and what do they entail? Lets start with CSP technology, which is most often mentioned in the context of the DII. CSP technology has a track-record at least as long as photovoltaic (PV) and wind technologies, with over 20 years of operating history from 354MW of power plants that were built in the 1980s and early 1990s in the Mojave Desert in California. These plants have been operating reliably, in fact exceeding design capacity, and have answered many basic questions such as the rate of breakage of glass mirrors and the impact of frequent on-off cycles on the steam turbines used. While there was a dearth of new plants during the period of cheap oil and fading policy interest in the 1990s, several new plants have now been built, mainly in the USA and Spain and many more announced.

What makes CSP technology so attractive in the context of solar export projects is the fact that they can deliver dispatchable power, a feature that their intermittent PV and wind cousins cannot offer in the absence of economic electricity storage options. CSP plants can either store the heat generated for release 'on-demand' or they can be co-fired with natural gas (as the Mojave Desert plants are) to extend operating hours and smoothen the production profile during cloudy days.

HVDC cables are proposed to transport the electricity from the North African deserts to the demand centres both locally as well as in Europe. These cables have been utilised in over-ground and sub-marine applications for over 50 years, increasing in distance and voltage over time. Only this year, the new 'NorNed' HVDC connection started transporting electricity through the North Sea between Holland and Norway on a 580km long, 700MW capacity cable.

Given the large scale of the projects

currently being discussed, how will this electricity be integrated into European grids? This is a question that Nur Energie has been studying for some time now, first with power system engineers from Imperial College in London and now with CESI, the Italian electricity network research institute. Utility-scale CSP plants are expected to deliver electricity in multiples of gigawatts to different interconnection points, so individual grid connection points might quickly be saturated. After having identified a feasible route through the Mediterranean to connect a utility-scale CSP plant from Tunisia, we have identified several potential interconnection points and are currently in the process of ranking them in terms of suitability, timing and ease of interconnection. An advantage here is that CSP plants can incrementally expand their capacity to co-incide with grid reinforcements. Optimal sizes are between 100MW and 200MW for an individual plant, and economies of scale will be achieved by building a series of plants at the same site. Thus, the roll-out of new CSP plants in the desert can coincide with the provision of adequate interconnection capacity on the European side.

...and where it is heading

Ah, the critics will retort, this is all very well, but what about the economics of all this? Feed-in tariffs for CSP plants in Spain are currently in the order of €0.27/kWh, so this will be a very expensive adventure in the desert.

While it cannot be denied that CSP technology is currently not cost competitive in most locations without support schemes, it also has to be pointed out that despite its long operating history, global investment in CSP has been very limited to date. Recent figures produced by the World Bank highlight this:

Global Cumulative Investment to-date:

Wind Energy	$200bn
Solar PV	$100bn
Solar CSP	$2.5bn

This suggests that the learning rate of CSP is likely to follow a steep reduction curve, as the installed base is low and each doubling of capacity can be achieved in relatively small increments. Furthermore, to use the jargon of the ‘technological innovation’ literature, no single ‘technological paradigm’ has yet emerged in the CSP industry. If anything, the traditionally dominant design of ‘trough’ technology is increasingly being challenged by the emerging ‘tower’ technology.

Tower technology holds several advantages. In order to understand the differences between the two, a short technical background is required: trough technology is installed in long rows of round-shaped (parabolic) mirrors, which reflect sunlight onto a tube in the centre of the mirrors. This heats a ‘heat-transfer-fluid’ (HTF), often oil, which runs through the tubes, collecting the heat and delivering it to a heat-exchanger in an adjacent power block, which transforms the heat into steam, thus driving a conventional steam turbine. These configurations currently have performance characteristics of 400C heat and 100bar pressured steam, with conversion efficiencies from solar to electricity of between 12–14 percent.

In contrast, solar towers produce steam directly, by reflecting sunlight onto a single receiver area at the top of a tower, which is surrounded by a field of thousands of mirrors. This removes the need for HTFs, as a solar boiler, placed at the top of the tower, absorbs directly the heat from the receiver area and heats the water inside to generate steam. This is fed into the turbine situated at the foot of the tower, further removing the need for kilometers of piping and reducing the losses and parasitic power consumption associated with this. BrightSource Energy, a solar tower technology provider with several advanced CSP projects in the USA, consequently aims for operating temperatures of 550C and 140–160bar pressures, thus vastly increasing the operating efficiency of the whole plant to >20 percent.

Together with the reduced need for specialist components and piping, this is set to deliver a step-change in costs. With both Siemens providing the turbines for BrightSource’s 440MW Ivanpah site in California, and Bechtel leading the EPC consortium, major industrial companies in the power and construction business are backing this concept. Among BrightSource’s equity investors, both venture capital companies such as Vantage Point and DFJ, as well as traditional energy companies such as BP and Chevron Technology Ventures provide equally strong backing.

Another major advantage of tower technology is that the higher operating temperature allows the plants to switch to a dry-cooling approach of the power block, which reduces water requirements by 90 percent compared to the water-cooled standard in trough technology. This is particularly pertinent for solar export projects in the desert environments of North Africa where water is a major bottleneck.

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Nur Energie’s models show that utilising BrightSource’s technology in the North African deserts and assuming moderate learning curves will deliver levelised costs of electricity (LCOE) that will be cost competitive with European wholesale prices much sooner than the timeframe of 2020, which is the current reference point for the EU’s renewable energy, as well as various carbon reduction targets. A timeframe of 2015 certainly seems realistic.

Desertec – The Major Challenges

So what is holding back the advent of large solar export projects? Three issues will be highlighted here:

1. Novel Regulatory Environment

As much as the technology is proven and costs are on the brink of becoming competitive, such projects would be placed into a novel regulatory environment, which does not exist today. Gas export pipelines have been typically regulated by special treaties and laws, both within the exporting and importing nations, as well as between them. Neither of those exist for electricity export cables between North Africa and Europe today.

While the EU has given priority to energy infrastructure investments and operates a neighbourhood investment programme with Northern Africa, no attempts have yet been made to formalise an investment framework that would govern the installation of numerous electricity cables across the Mediterranean, either on a merchant-basis or in cooperation between national grid operators. However, a first interconnection project between Italy and Tunisia has now commenced with agreements on a bilateral basis.

Furthermore, besides novel South–North electricity cables, an expanding base of large-scale solar plants in Northern Africa will require reinforcements of electricity links between Northern African countries as well. Such links could be an important co-benefit of increased South–North electricity trade and increase intra-African trade of electricity and associated developments such as the provision of fresh-water through desalination.

2) 'First-of-a-kind' Risks

As much as the opportunity of solar export plants is enormous, the complexity of the task and the risks involved are significant hurdles in forming an industrial consortium to match them. The Desertec Industrial Initiative is an expression of the recognition of these complexities, with no one member firm willing to explore a solar export project on its own.

Agreements are needed to mitigate such issues as sovereign and electricity offtake risks, at least for the first plants. A model could be the loan guarantees currently provided for renewable energy projects in the USA, as well as precedents from the USA's nuclear policy. The 2005 Energy Policy Act provides financial guarantees against cost-overruns and construction delays of the first six nuclear reactors, as well as production tax credits for the first 6000MWh of annual production for the first eight years of operation of new nuclear power plants. Feed-in tariffs for imported electricity could be an alternative approach.

Our conversations with banks indicate that the arrangement of project finance will not be a major hurdle if these issues are addressed. CSP technologies have been project financed in the past and lending into Northern African countries is frequently occuring, often in syndications with multi-lateral financing institutions or development banks. The offtake in a mature electricity market such as the European adds to create a stable investment framework.

3) Scepticism in North African Countries

Currently, the increasing euphoria over Desertec in Europe is unmatched in the North African region. National development plans are often unambitious and lack clarity and detail with respect to crucial questions over finance and regulatory certainty. Furthermore, there is an aversion by North African countries to implement a perceived 'black box' technology from Europe or the USA, without deriving any local benefits in the form of technology transfer and know-how.

For Desertec to succeed clear commitments from European countries along those lines are required. In fact, one of the rationales for the World Bank's CTF programme is the recognition that the MENA region hosts one of the most promising solar radiation levels for the large-scale implementation of CSP projects, in contrast to the total potential in Europe itself. Decomposing solar tower CSP technology, and to a lesser extent trough technology, it can quickly be seen that most individual components are amenable to mass manufacturing by light industry clusters, precisely matching current industrial structures in North African countries such as Tunisia and Algeria. In fact, most of the know-how in solar tower technology is in the design, control and operations of the solar field. This can be transferred through technology collaboration and training in the actual implementation of CSP projects, which is precisely the objective of the Desertec initiative.

Recent policy developments are promising. The new EU Renewables Directive explicitly opens the door for member countries to support export projects and allows them to count towards their national renewable energy targets, subject to certain conditions. Initiatives such as the Mediterranean Solar Plan of the Mediterranean Union, the World Bank's $750m CSP lending facility for the MENA region and the DII are mobilising private and public sector actors on both sides of the Mediterranean Basin. Hence, a policy and investment framework for solar export projects has never been closer.

In summary, it is easy to see why advocates of the Desertec initiative have called for an 'Apollo'-programme to turn the vision of large-scale solar-export projects into reality. Several political, techno-economic and financial hurdles have to be overcome in order to create the conditions in which significant investments will flow into such projects. Still, the scale of the solution that Desertec offers can pay back these initial efforts many times over. Just 0.3 percent of the North African deserts' surface area would theoretically be required to serve the electricity and desalinated water needs of the entire MENA–EU region. A small fraction of this would already allow a significant percentage of Europe's electricity demand and renewable energy targets to be met. This is the backdrop to the energy devoted by many academics, policy-makers and private companies to solve this jigsaw and make Desertec a reality, not in the distant future but much sooner than many sceptics might think.