CSP *promises* *24-hour* solar power

Once considered an also-ran, concentrated solar power is getting a second look. A level market playing field and new advances in CSP technology may make it an essential form of renewable energy. Chris Tattersall reports on the technology's resurgence.

The power tower at KAM's demonstration CSP plant in Jülich, near Cologne, Germany

"CSP has the unique advantage over wind and solar PV that primary energy storage can be directly integrated into the power plant…"

Reinhold Frank, Alpiq/KAM

By the numbers, concentrated solar power (CSP) looks like a technology that never really made it: the global installed base of photovoltaic solar power (PV) is 200 GW and growing by double digits every year while CSP has a global installed base of only 4.5 GW.

In the beginning of the 2000s, many CSP projects were built. But around 2005, things changed: PV and wind took off, and investor interest in CSP lagged.

Now CSP's fortunes may be on the verge of a major shift. Looking forward to a future when PV and wind are likely to be more exposed to market prices and carbon pricing should slowly increase, CSP's storage capacity may well lead it to a renaissance.

The USP of CSP

The case for CSP begins with the fact that both PV and wind power have no built-in storage and generate electricity at irregular intervals. This creates a major challenge for system operators. "The correlation of wind and PV energy means that, as they produce, they force down the wholesale price – just look at German wholesale prices over a sunny and windy lunchtime," says Reinhold Frank, CEO of Kraftanlagen München GmbH (KAM), a CSP technology developer and EPC provider to the energy industry, and a wholly owned subsidiary of Alpiq Holding AG, where Frank is a member of the Executive Board.

Feed-in tariffs mean that PV and wind energy producers don't need to be concerned with this problem right now; they get paid no matter when and how much they produce. However, if these two renewables are eventually exposed to market prices, they will be much less economical as power producers would need to install massive batteries to delay the sale of their electricity until after sunset, when electricity market prices are higher.

Enter CSP with storage. CSP generates power more steadily by superheating a medium that stays hot enough, for long enough, to store heat far into the night, making it possible for the turbines to keep on spinning at a steady rate around the clock. The (approximately 6–12 hours) storage capabilities of CSP give utilities the ability to provide their grids with a much more even power load – and without the investment in battery storage other off-hour renewable systems require.

This reserve power can be managed minute by minute, and dialed up or down in a way that helps keep the overall load well balanced and system costs down. A 2011 study by the European Academies Science Advisory Council (EASAC) found that CSP had the same characteristics as a mid-level, mid-load fossil fuel plant.[1] In Spain, CSP generators can deliver 30% power ramps in less than an hour, enabling REE, Spain's grid operator, to treat it as just another dispatchable energy source.

The fact that CSP operates on a thermal principle, similar to most traditional power plants, also means it can be integrated more easily with gas power plants than can wind and PV stations. If its superheated core is still not powerful enough to generate all the electricity needed, the fact that CSP is thermal makes it easy to incorporate a fossil-fuel generator that kicks in when needed – a huge advantage over PV and wind, EASAC analysts note.

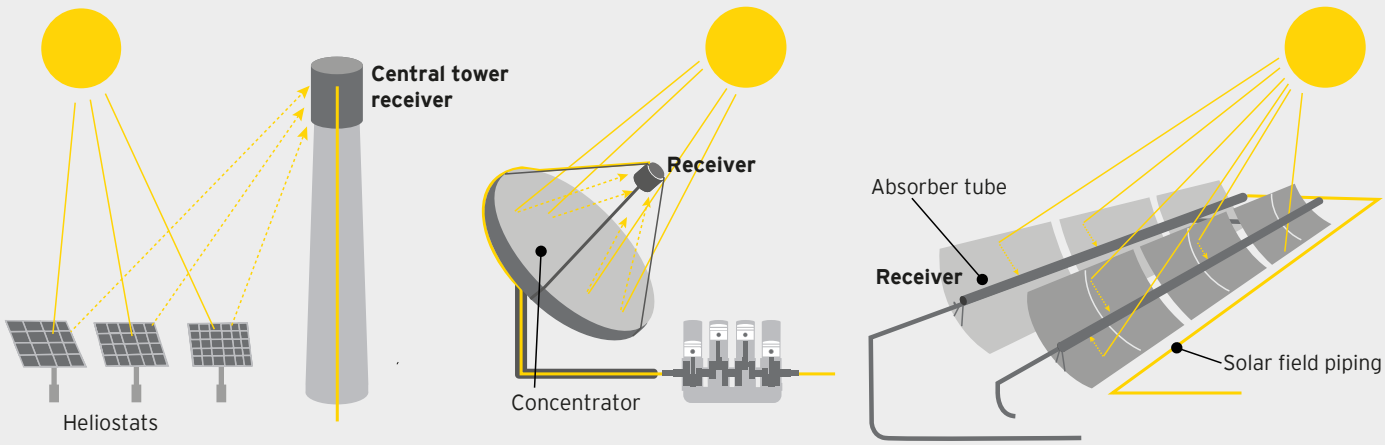
Spain leads the way

Despite all these advantages, CSP is not yet getting its due outside of Spain, currently home to half the world's CSP capacity (2.5 GW). Two factors are making it more successful there than in most other countries, including such renewable energy giants as Germany. First, Spain has more sunny days than many other countries. Second – and more important – the Spanish feed-in tariff structure encourages evening production.

As more PV and wind power are added to the energy mix, these advantages should become increasingly attractive. Globally, up to 50 GW in PV capacity is expected to be added in total this year, according to German solar association BSW-Solar,[2] and as more PV is added to the grid, the need for more demand-responsive generation will certainly rise.

1. Concentrating solar power: its potential contribution to a sustainable energy future, European Academies Science Advisory Council, 2011.
2. BSW-Solar study, quoted by Solarlove.org, 15 July 2015.

Figure 1. Three main designs for CSP plants



Power towers: a large heliostat field concentrating the radiation on a common receiver on top of a tower, superheating a thermal fluid such as molten salt that can be used to drive a turbine. The latter either directly produces a high pressure for a turbine or its thermal energy is used to boil water that eventually drives a steam turbine.

Dishes: circular mirror paraboloids shaped like satellite dishes, with a diameter of up to a few tens of meters, concentrate light on a single receiver. The reflected light heats the receiver, which heats hydrogen or helium tubes that drive four piston cylinders and turn a crankshaft that drives an electric generator.

Trough: long rows of parabolic mirrors focus their reflected heat on central pipes filled with a thermal fluid. The thermal energy of the fluid is subsequently converted into mechanical energy by means of a steam turbine.

Source: EY analysis

KAM executives predict that when the renewable share reaches 30%, grid operators will begin to face load management issues. Operators will seek either to rely on traditional fossil fuel-generated power with a short deployment time to compensate for renewable energy's night deficit or to invest in greater grid flexibility and capacity to handle the large decentralized power generation fluctuations.

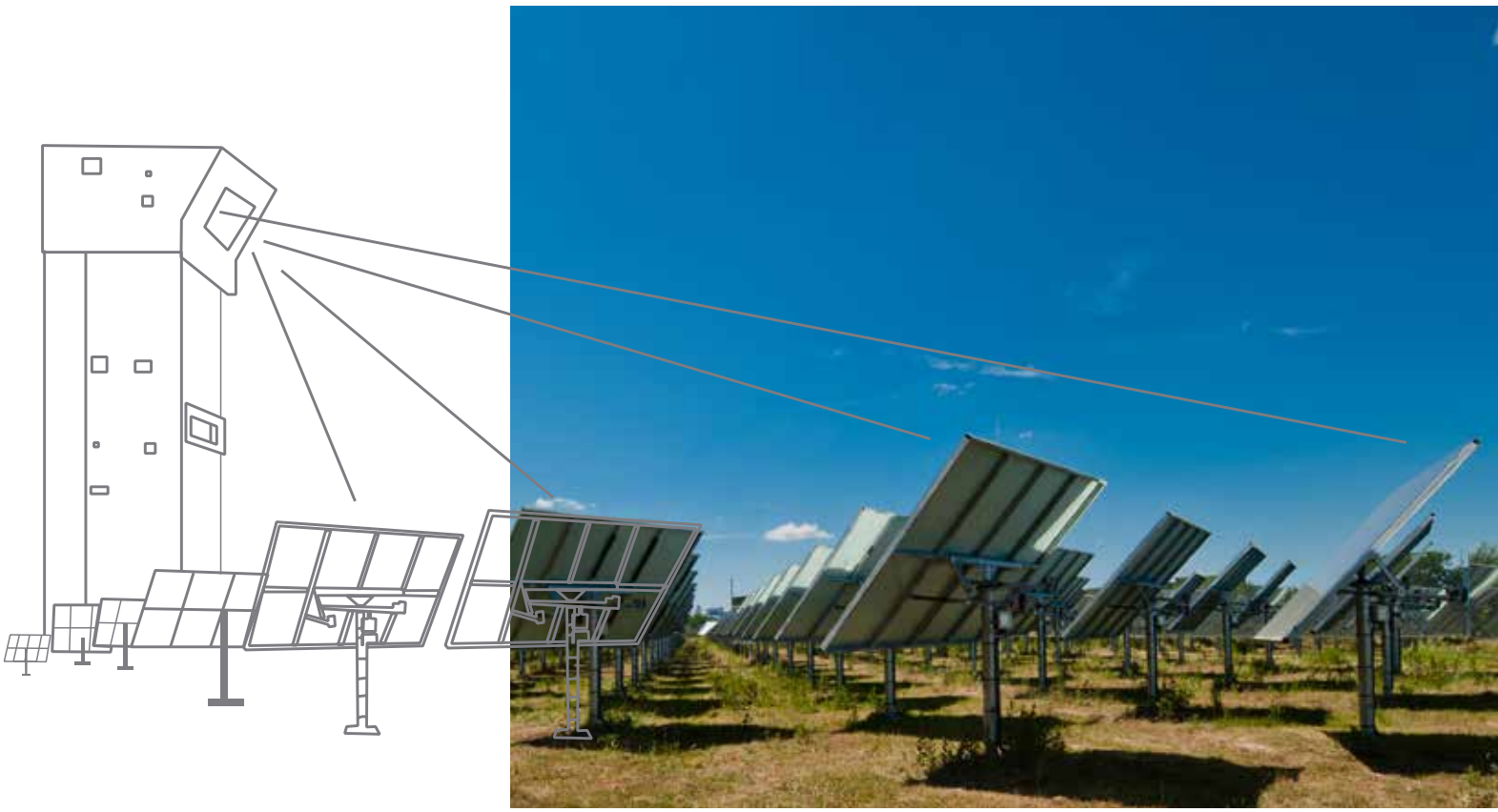
In places as varied as South Africa, Morocco, Saudi Arabia and Chile, most of the new CSP projects in recent years have included power storage features, often to take advantage of high evening power prices. In some countries, storage is now required by legislation. "Storage is the only way we can avoid investing too much into the grid because nobody has the money," says Frank.

Understanding CSP

CSP systems use mirrors to heat a thermal fluid, usually water, oil, molten salt or a gas. The hot fluid either produces a high pressure or it passes on its thermal energy via heat exchangers to a secondary thermal fluid that produces a high pressure. The high pressure fluid then pushes a piston or drives a turbine. Most of the world's 90+ CSP plants are designed in one of three ways: with an array of mirrors that superheat a central tower, a large dish of mirrors focused on a central receiver, or long troughs that superheat thermal fluid in pipes (see Figure 1).

Of the three technologies, the dish appears to be least attractive because of its high cost and relatively poor economies of scale. Its installed base is almost negligible.

The two more common forms of CSP, linear and central receivers, have advantages and disadvantages. Developers select one form or another depending on solar irradiation conditions, terrain (topography), size of plant and the target application.



The heliostat field around the central tower receiver at KAM's demonstration plant in Jülich, near Cologne, Germany

Until recently, linear receivers (particularly parabolic troughs) constituted the majority of the installed capacity. Looking at the project pipeline, however, it is clear that the use of central receivers seems to be rising, perhaps because energy storage can be integrated more easily into a central receiver system.

Breakthrough in power tower CSP technology

KAM engineers say the innovations they are making at their demonstration plant in Jülich, near Cologne, Germany (see photos, page 4 and above), make CSP more efficient in energy production, less costly to build, cheaper to maintain, safer to use and more environmentally friendly. Their secret: a lot of hot air.

Current CSP designs use a variety of fluids to transfer the heat the system generates, usually water, molten salt or oil. Any leaks in oil- or salt-based CSP can pollute the environment, such as the surrounding soil or atmosphere. Performing maintenance work around moving hot salt or oil is dangerous, normally requiring the whole plant and piping to cool before any major maintenance work can be done.

KAM's design uses unpressurized air instead of oil or salt as its heat transfer medium. "Using air as the transfer medium greatly reduces the safety issue since the chances of serious burns caused during maintenance are much lower than with water, salt or oil," explains Stefan Linder, Head of Technology and Innovation at Alpiq, KAM's parent company. It also solves the environmental issue since a leak simply means air escapes rather than salt or oil polluting the environment.

Using air as the transfer medium makes a plant quicker and easier to maintain as it takes less time and effort to cool down. Nor does air get stuck in the piping as the plant cools down: "When you have molten salt, you must under all circumstances avoid solidification in the piping, which would cause major damage to the system. Hence, you either need to keep pumping hot salt around at all times or you must fully discharge the salt from the pipes and fill them with an inert gas during extended operation interruptions. This results in risky, expensive and time consuming scheduled maintenance and emergency shutdown procedures," explains Linder.

The air approach also reduces costs. "We do not require long and expensive high pressure piping systems, and we can work with a solid state storage," Linder says. "For storing the heat, the hot air is simply pumped through the storage media - silicon carbide bricks with channels that let air pass through and thereby exchange the heat."

KAM's design is also more energy efficient due to the high achievable temperature (680 degrees centigrade) of the heat transfer medium, air. This is made possible by the very high concentration of solar radiation on a small focal point on the top of the receiver tower (approximately 1 MW/m^2), which heats the absorber surface to approximately 1,000 degrees centigrade, Linder explains.

KAM is not content with the simplification of air and is exploring a variety of additional ways to minimize the levelized cost of energy of its CSP technology. "We are looking at how we can keep the function, quality and reliability, but make it as inexpensive as possible," Frank says.

As with most other renewables, CSP is not yet cost-comparable with fossil fuel plants. But Linder predicts that it will eventually be competitive without

"CSP will eventually be cost-competitive without subsidies as more costs are squeezed out of the system."

Stefan Linder, Alpiq

subsidies as more costs are squeezed out of the system and assuming the price of carbon dioxide rises.

Opportunities in water-constrained locations

Beyond power, CSP may also create some other interesting opportunities for dry and sunny places. Like every thermal power plant, CSP turbines throw off a lot of exhaust heat, which can be incorporated into a desalination process.

Desalinating water is one of the world's fastest-growing and most pressing power needs.

Depending on the process, desalination consumes as much as 2.5–3.5 kWh per cubic meter of water, according to a 2012 study by the International Renewable Energy Agency (IRENA). Even now, about 0.4% of global electricity is consumed in desalination, and demand for water continues to grow. In the MENA – Middle East and North Africa – region alone, desalinated water capacity is expected to rise to nearly 110 million cubic meters in 2030, up from 21 million in 2007, according to IRENA.

IRENA found that the flexibility CSP offers because of its two signature features – its capacity to store energy and its easy integration into a hybrid system – could make it an attractive power source for the process.

Utilities hold the key to future development

Ultimately, technological advantages will take CSP only so far, Frank believes. Utilities will need to lobby their regulators and governments to realign market designs in a way that allows CSP to compete on a level playing field with PV and wind: "The arguments have to come from a utility, not a vendor," says Frank. ■

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Reinhold Frank

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Reinhold Frank is an Executive Board member and head of Energy Services of Alpiq Holding AG. In 2013, he was also appointed CEO of Kraftanlagen München GmbH, a wholly owned subsidiary of Alpiq. His career has encompassed board and executive roles in European utilities and construction, including Germany's RWE and Hochtief AG and Vychodoceska Plynarenska in the Czech Republic.

Stefan Linder

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Prior to joining Alpiq in 2014, Stefan Linder held a variety of R&D, operations management and business development roles at ABB, the power and automation giant.