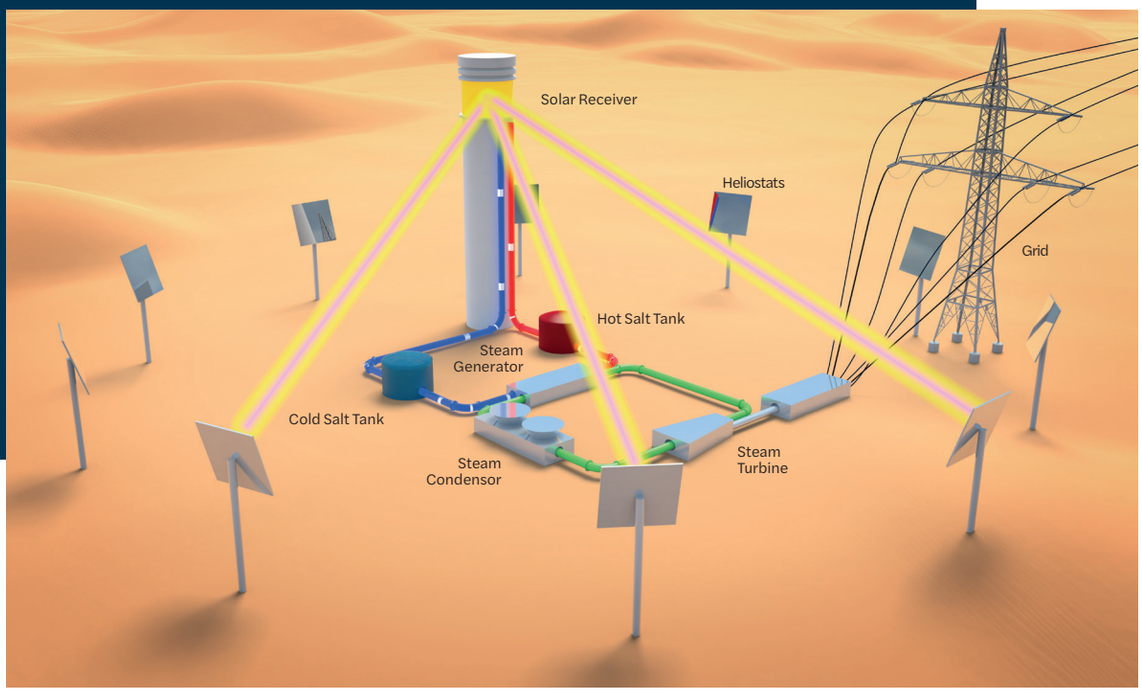
Concentrated Solar Power

Solar Receivers and Steam Generators

johncockerill.com/energy

John Cockerill



Molten salt power tower principle

Central Tower **Solar Thermal Electricity**

On central tower solar thermal power plants, the solar field consists of thousands of heliostats (mirrors on mounting poles with tracking capability) located on the ground, each of them individually controlled to concentrate the solar rays towards a receiver located at the top of a tower.

The heat flux reaching the receiver can exceed 1000 kW/m², which represents more than 1000 times the natural solar flux at the most exposed places on earth!

The receiver consists of vertical heat exchanger tube panels through which a heat transfer fluid (water or molten salt) absorbs the energy of the concentrated solar flux.

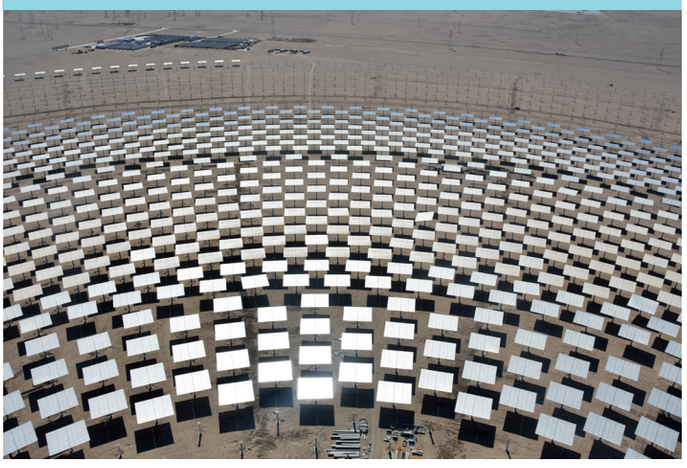
Thermal energy is used to generate electricity through a thermo-dynamical process, typically by generating superheated steam to feed a steam turbine that drives a generator as in the classic process of most power plants.

Strengths of Power Tower Technology

- Higher concentration ratio allow higher temperatures, and thus **better efficiency**.
- The receiver is capable of withstanding high pressures. This allows direct production of **high pressure superheated steam** (up to 185 bars) in the receiver (in the case of Direct Steam Generation).
- A short and mostly vertical piping layout allows fast and easy drainage of the heat transfer fluid and makes the receiver **the safest arrangement for molten salt plants**.
- No need for dangerously flammable and polluting thermal oils used in parabolic trough plants, which limit the generated steam temperature to below 400°C, with a negative impact on the plant efficiency.

More efficient than photovoltaic

This thermodynamic process is specific to Solar Thermal Electricity and much more efficient than any photovoltaic process. Furthermore, the possibility to economically store thermal energy gives a serious advantage to Solar Thermal power plants compared to most renewable energy sources.



The central tower solar thermal plant of Upington (South Africa) equipped with a John Cockerill receiver

Electricity Production **24h/day**

This Wind and sun energy sources are uncontrolled; they induce a fluctuating electricity production. The network must therefore adapt quickly and efficiently to compensate any power drop. Solar thermal power plants represent one of the best efficient energy sources as they do not generate power fluctuation. They can feed the network anytime instantaneously adapting their production to the demand. That is what is called a « dispatchable » electricity production. Solar Thermal Electricity plants therefore contribute to the stability of the network like any conventional power plant. They also allow an electricity generation 24 hours a day!

Molten Salt Plants
Dispatchability and Overnight Power Generation

The best way to insure dispatchability or even overnight electricity production is to store the absorbed solar energy in molten salt: a low-cost, flame-proof and non-polluting fluid.

How does it work?

The solar receiver first converts the absorbed solar energy into thermal energy by heating molten salt, which is stored in the hot molten salt storage tank. Steam can then be produced on demand by pumping the hot molten salt through a steam generator. Cold molten salts are returned to a cold molten salt tank, from which they are sent to the solar receiver to be heated again.

Molten salts freeze if their temperature goes below around 230°C. It is one of the main challenges with molten salt plants. Thanks to their short and vertical piping layout, allowing fast and easy drainage, central towers are the safest solution for a direct heating of molten salts in the receiver.

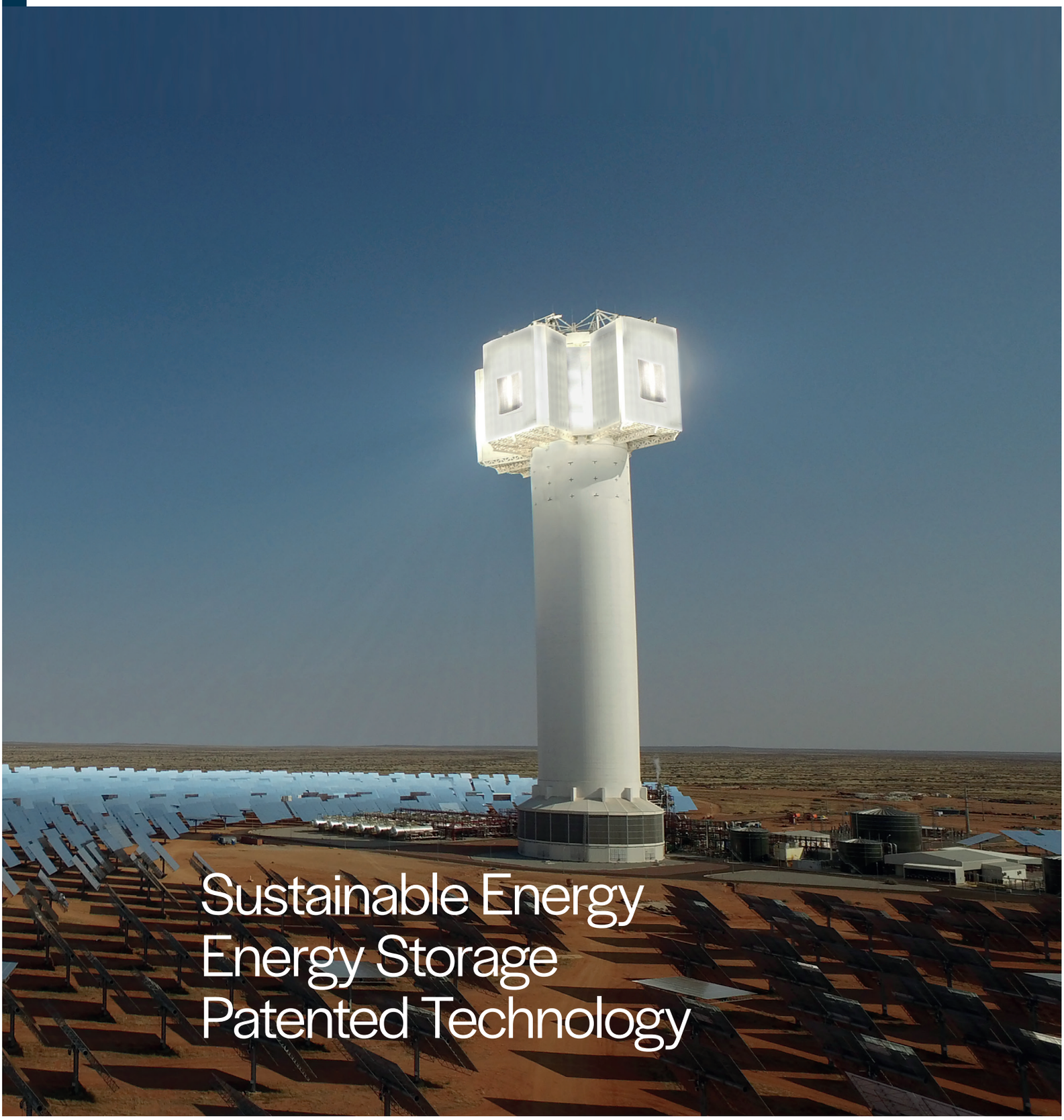
Direct Steam Generation Plants
Economy and High Efficiency

In a direct steam generation thermal solar plant, the solar receiver directly generates steam for the turbine, without the need for another heat transfer fluid. As they do not require separated steam generators, such plants are economical and allow the highest efficiency. However, given the necessarily high pressures involved, steam storage tanks are thick, heavy and expensive.

Direct steam generation is, therefore, not the best adapted technology for a large energy storage. In this case, a molten salt plant will be more efficient.

John Cockerill's receivers:

Heart of the plant State-of-the-Art



John Cockerill thermal solar receiver Khi Solar One (South Africa)

John Cockerill's Receivers, **a Jewel of Technology**

Located at the top of tall towers, John Cockerill's receivers collect the concentrated solar energy and transfer it either directly into high pressure steam (Direct Steam Generation) or into hot molten salt. These receivers operate in extreme conditions, which makes them a jewel of boiler engineering and technology.

The main challenges come from the very **high energy fluxes** involved: above 1000 kW/m², i.e. several times more than what is reached in conventional fired boilers. This leads to metal temperature locally exceeding 700°C, requiring to use **special materials** like stainless steels and nickel alloys.

High temperatures induce thermal expansion, stresses, creep, fatigue...

John Cockerill's expertise as a boiler designer allows to control these phenomena and mitigate their effects. Calculations methods had to be refined to verify the **lifetime** of the equipment, which operates under highly fluctuating conditions.

A major operational risk for the receiver is to have it overheated due to a locally excessive incident flux. This might cause the destruction of a receiver panel in a few seconds. To mitigate that risk, John Cockerill developed a system to closely **monitor the thermo-mechanical behavior** of the panels thanks to a network of infrared cameras. The system also evaluates in real time the **thermal stress** at every point of the panels. In case the maximum acceptable stress is locally approached, a signal is sent to request an adjustment of the energy directed toward the receiver. This allows to always operate **at the maximum capacity without any risk** of damaging the receiver.

John Cockerill's Steam Generators: **innovation, reliability and efficiency**

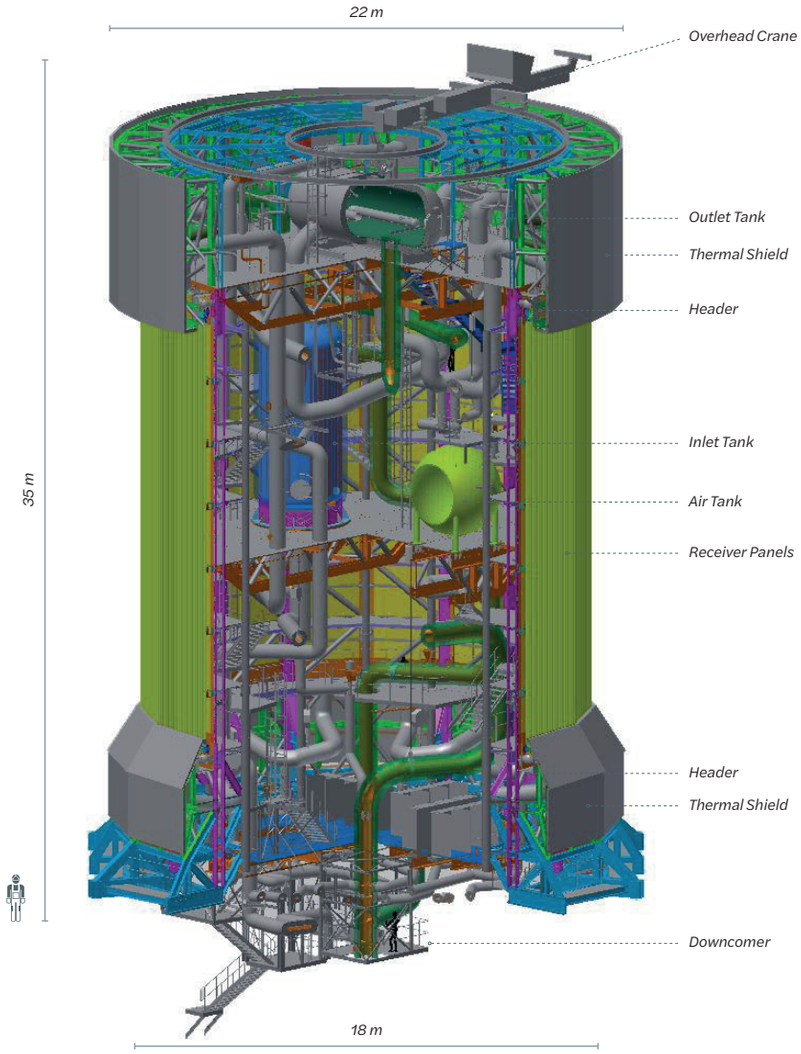
John Cockerill's latest product in CSP

In 2017, John Cockerill celebrates its 200 year anniversary. During this extensive period of time, John Cockerill has gained an invaluable expertise in boiler engineering which is at the disposal of the CSP industry. John Cockerill offers another key component of CSP plants: the Molten Salt Steam Generator (MSSG), which consists of a group of exchangers transferring heat from the hot molten salt loop to the water cycle of the power plant. .

John Cockerill Molten Salt Steam Generators: key features

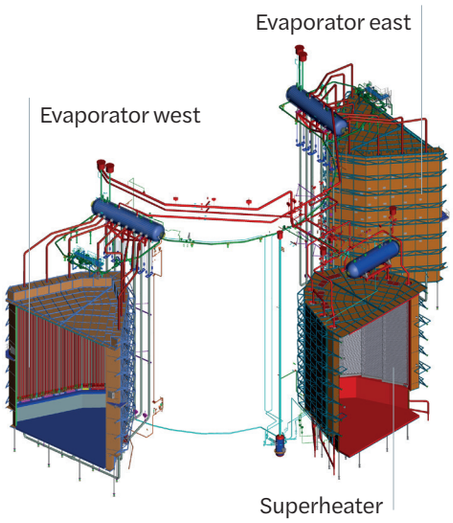
In the near future, CSP plants are expected to work as Peaker Plants. In other words they will be subject to frequent start-ups in order to generate electricity whenever required by the electricity grid, so that operators will be able to take advantage of the dispachability of CSP plants. As a consequence, Molten Salt Steam Generators will have to deal with daily start-ups which have to be as short as possible to maximize electricity production and installation profits. For this reason, John Cockerill has developed an innovative concept of heat exchangers which have a wide range of operation, are able to withstand high temperature ramps and are designed for frequent start-ups. Moreover, great attention was paid to make these heat exchangers as reliable as possible, especially in regards to corrosion issues related to the use of Molten Salt at high temperature. Finally, thanks to its innovative design, John Cockerill has drastically reduced pump consumption and mitigate the risk of fouling in these heat exchangers. As a result, John Cockerill has optimized energy production over the lifespan of the power plant.

Molten Salt Receivers

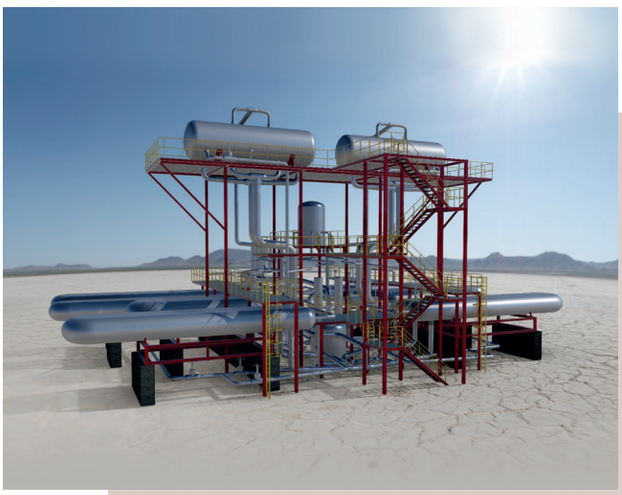


Direct Steam Generation Receivers

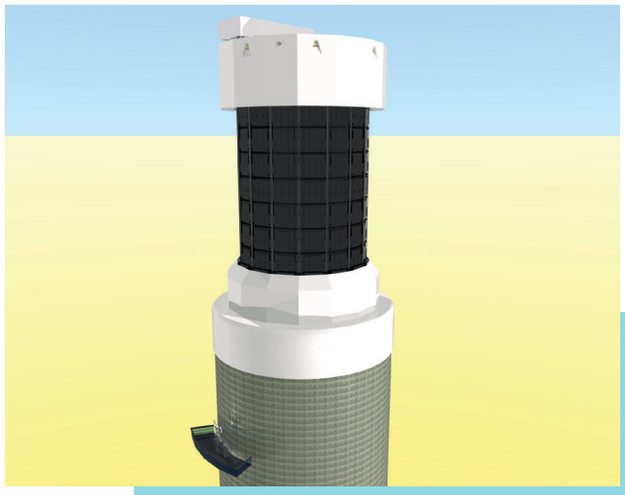
Cavity type design

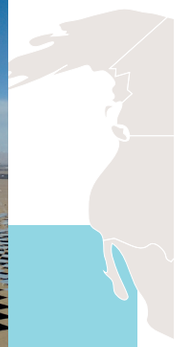


Steam Generator



The Solar reference list





2018 – Dubai Solar Park Phase 4 (UAE)

- World's Tallest Solar Tower!
- Scope: solar receiver
- Customer: Shanghai Electric Brightsource JV
- Technology: Molten Salt
- Installed power: 100 Mwe
- Absorbed Power: 600 MWth
- Storage time: 12 hours

2017 – Haixi (China)

- First western solar receiver in China!
- Scope: solar receiver
- Customer: Sepco 3
- Technology: Molten Salt
- Installed power: 50 MWe
- Absorbed Power: 280 MWth
- Storage time: 12 hours

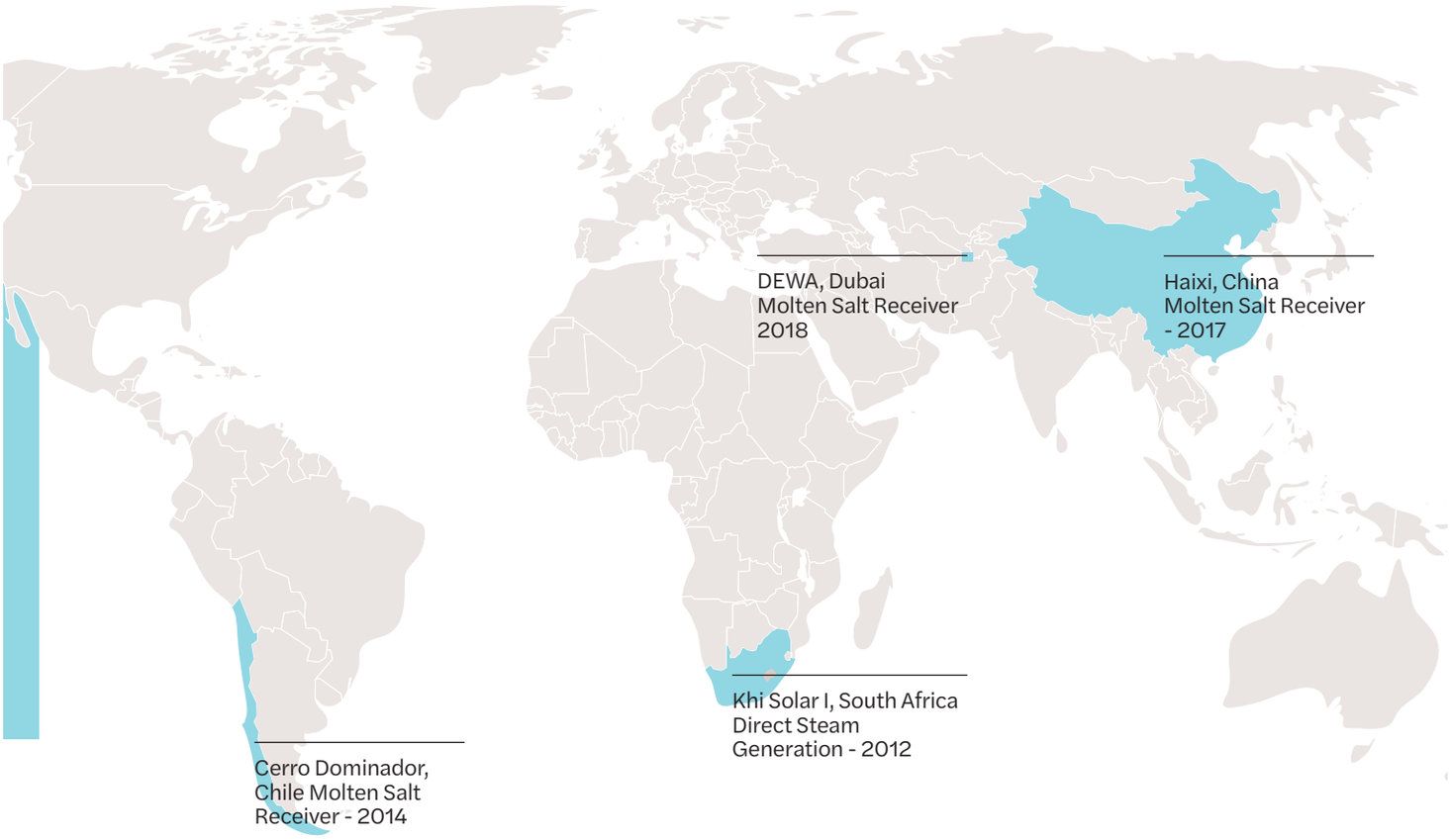
2014 - Cerro Dominador (Chile)

- First Solar Tower in South America!
- Scope: solar receiver
- Customer: Abengoa/Acciona
- Technology: Molten Salt
- Installed power: 110 Mwe
- Absorbed Power: 760 MWth
- Storage time: 17,5 hours

2012 - KHI Solar One (South Africa)

- First Solar Tower in Africa!
- Scope: solar receiver
- Customer: Abengoa
- Technology: Direct Steam
- Installed power: 50 MWe
- Absorbed Power: 250 MWth
- Storage time: several hours

John Cockerill's Achievements



Timeline

In **2018**, John Cockerill Energy was awarded the supply of a molten salt receiver for the Dubai Solar Park Phase IV Solar tower project in Dubai, capable of absorbing a thermal power of 600 MWth, to equip a molten salt Solar Thermal Electricity plant of 100 MWe, with an energy storage capability of 12 hours. **The world's tallest solar tower**!

In **2017**, John Cockerill Energy was awarded the supply of a molten salt receiver for the Haixi project in China, capable of absorbing a thermal power of 280 MWth, to equip a molten salt Solar Thermal Electricity plant of 50 MWe, with an energy storage capability of 12 hours. **The first western solar receiver in China**!

In **2014**, John Cockerill Energy was awarded the supply of a molten salt receiver for the Cerro Dominador project in Chile, capable of absorbing a thermal power of about 760 MWth, to equip a molten salt Solar Thermal Electricity plant of 110 MWe, with an energy storage capability of 17.5 hours. **The first solar Tower in South America**!

Its key features include:

- **Patented insulated airtight casing**
- **Designed to be erected on the ground and lifted in one piece to the top of the tower**
- **Patented IR temperature and stress real-time monitoring system**
- **Patented Maintenance System**

In **2012**, John Cockerill was awarded a contract for the delivery of a direct steam generation solar receiver (cavity type) for the 50 MWe Khi Solar One CSP plant near Upington (South Africa). **The first solar Tower in Africa**!

In **2008**, John Cockerill Energy launched its first development of a cavity type solar receiver producing superheated steam (530°C, 130 bars) directly usable by conventional steam turbines.

The Power to Change the World

It is from the heart of its history stretching back more than 200 years that John Cockerill Energy draws its expertise in the production of steam, which has led to it being recognized worldwide on the market for the conception and supply of heat recuperation boilers.

Resolutely turned towards the future, we proudly incarnate the bold spirit of an entrepreneur and we have extended our know-how in order to respond to the needs of our times, by developing innovative solutions to encourage access to energy, just like our founder in his own times.

It is from this knowledgeable mix of tradition and innovation that we draw our own energy. And it is across the whole world that John Cockerill Energy makes its mark through its technological know-how and its mastery of project management thanks to our Belgian, American, Canadian, Chinese and Mexican teams and our recuperation boiler licensees, Wuxi, S&T and Larsen & Toubro which respectively cover China, South Korea and India.

Together, we all work to facilitate access to green energy!

Heat Recovery Steam Generators

Solar Tower Receivers & Steam Generators

Industrial Boilers

Energy Storage

Hydrogen

After-Sales

Welding Expertise Center

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