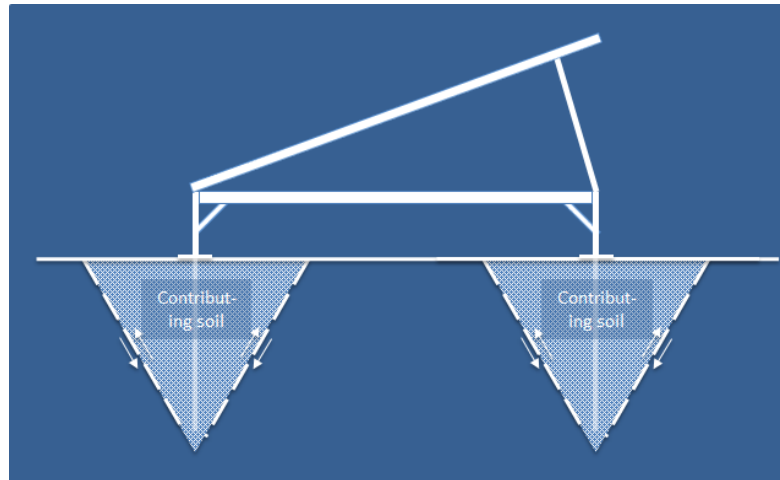


## Nuance Energy/THEnergy Report

### Modular, semi-portable mounting systems for solar in the mining sector



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**NUANCE ENERGY**  
Leading Solar Innovation™

**THE ENERGY**  
the microgrid consultancy

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## 1 Introduction

Mining is an extremely energy intensive undertaking. Electricity generation is typically, after labor, the second most important cost factor in mining operations. It is no surprise that miners are interested in the benefits of renewable energy. The adoption process for renewable energy in mining is slow - this is normal for new technologies. In the recent mining crisis, with high pressure on commodity sales prices, the priorities have also shifted from upstream to downstream.

The turbulent mining markets have calmed down a bit in recent months. This will allow mining executives to focus more on strategic topics such as the integration of renewable energy in their energy mix. In 2017 and 2018, we saw several major announcements of solar energy projects at offgrid mines.

The business case for off-grid solar is typically excellent. This is mainly due to the fact that diesel power generation is on average more expensive than power from the grid. This means that renewables are benchmarked against expensive diesel power and not against subsidized grid electricity. The following figure gives an overview of announced and already finished renewable projects in mining.

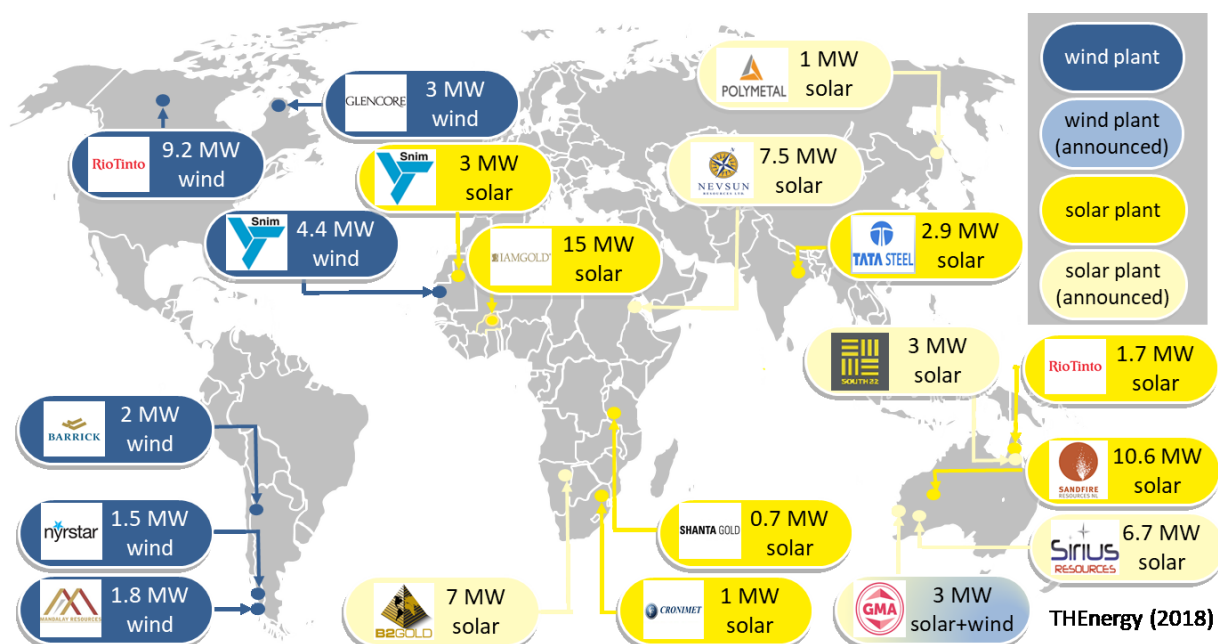


Figure 1: Major on-site solar-diesel or wind-diesel hybrid power plants at remote mines

In select regions, mining companies were also involved in grid-connected projects, notably in Chile. In the north of the country, generation capacity was missing, and electricity was highly expensive. Several mining companies closed long-term power purchase agreements (PPAs) with independent power providers (IPPs) that were investing in solar assets and selling the electricity through the grid to the mines. In Mexico, we find similar approaches for wind energy projects.

For the sweet-spot of large-scale off-grid projects, special requirements need to be met by solar power plants. While the first projects were built to a large extent with standard components, in the meantime more and more specialized solutions have been developed that allow for improving the performance of the plant and optimize the costs at the same time. This study will focus on advancements that have been achieved in the field of mounting systems for off-grid mines.

## 2 Power Requirements for mines

### 2.1 On-grid mines

Many of the large mines are grid-connected. Grid power is often rather inexpensive. Depending on actual electricity costs, solar and wind energy may contribute to further reduce electricity costs. The main focus is on generating electricity as cost-effectively as possible, which also translates into optimizing capital expenditures (CAPEX) and leveraging economies of scale by building large solar power plants. The grid also allows for separating the location of solar power plants and mines. One large solar power plant may provide electricity for several mines. The generation concept is much more similar to traditional approaches to power generation as it is a more central concept. Mines either commit to supplying long-term energy from renewable energy generation assets or just procure solar or wind energy as an additional element of their electricity mix.

In many mining countries – especially in developing countries, the main concern of miners is not so much the electricity costs, but rather issues regarding the reliability of the electricity supply. Renewables as intermittent energy sources will not directly provide a solution to these issues. PPAs for grid-connected mines are rather standard and do not require particular features regarding the technology. This is different for off-grid mines.

### 2.2 Off-grid mines

Diesel or heavy-fuel oil is normally the primary source of energy for remote mines that do not have a grid connection. The cost for powering offgrid mines is typically very high. In comparison to large-scale grid-connected power plants, diesel generators and heavy-fuel oil engines are also less efficient. Additional costs occur due to the remoteness of these mines. Transport accounts for a disproportionately high cost factor. Often a significant amount of fuel is also lost or stolen during the transport or when stored at the mine. Indirect costs are further increased by maintenance requirements for diesel gensets and heavy fuel oil engines. Finally, diesel prices are very volatile and price fluctuations are a major risk factor regarding operating costs. Financial hedging is typically rather expensive.

The costs of renewable energy have come down significantly in recent years. This is particularly valid for solar power. Given that many mines are in areas with high solar irradiation such as in Africa, South America, or Australia, the costs are even disproportionally low. Normally, solar energy is significantly less expensive than electricity generated by diesel generators or heavy-fuel oil engines. Displacing or partly replacing these fossil fuel-based energy sources by solar power allows for reducing the overall energy costs of the mine. Solar power is an intermittent power source and the actual output depends on

- the time of the day,
- local weather conditions,
- seasonality.

These factors may be compensated by energy storage. In many cases, energy storage is still not cost-effective enough to fully run a mine on solar plus batteries. The objective is rather to combine intermittent solar power with diesel or heavy fuel gensets in an intelligent way.

### 2.3 Challenges

#### 2.4 Solar for reducing diesel consumption in remote mining applications

In so-called solar-diesel hybrid approaches, solar power plants and diesel generators are connected to provide a stable output to offtakers such as mines, factories, telecommunication towers or off-grid towns. Solar power is used to reduce diesel consumption. Whenever the power demand is higher than the solar output, the gap is bridged with additional power from diesel gensets.

Unexpected power drops, for example from clouds that shade the solar PV array, are also compensated by the diesel genset. In the simplest concept, the diesel genset runs constantly in order to provide a sufficient spinning reserve in case of full shading. This means that the diesel generator cannot be switched off which also has adverse effects on the total amount of diesel to be reduced by solar.

More advanced concepts allow for a higher penetration of solar power. Diesel gensets might be fully switched off in periods with high solar irradiation. A battery energy storage system is used for bridging the time that is needed for the diesel generators to restart. This means that in case of shading, the spinning reserve is first provided by the batteries. This approach allows for a higher share of solar energy in the system. Surplus solar energy is stored during the day with batteries and used for night-time consumption. The downside is that the battery costs are still relatively high.

The increasing number of solar-diesel hybrid power plants that have been built in the last years is to some extent related to innovations in business models. PPA concepts have been successfully applied to off-grid applications. This means that miners do not need to invest their own capital to use solar energy. A mid to long-term commitment in the form of PPAs is sufficient. IPPs are then responsible for the investment in the solar infrastructure, and mines buy the solar energy by the kilowatt-hour.

In these remote mining applications without grid-connection, the solar power plants have to be built near the mine. As an increasing number of projects has been finished in recent years, tailor-made technology solutions have been conceived. Challenges regarding the integration of solar, forecasting of the generated power depending on the specific irradiation, the flexibility of diesel gensets, and the portability of solar arrays have been addressed by new technology.

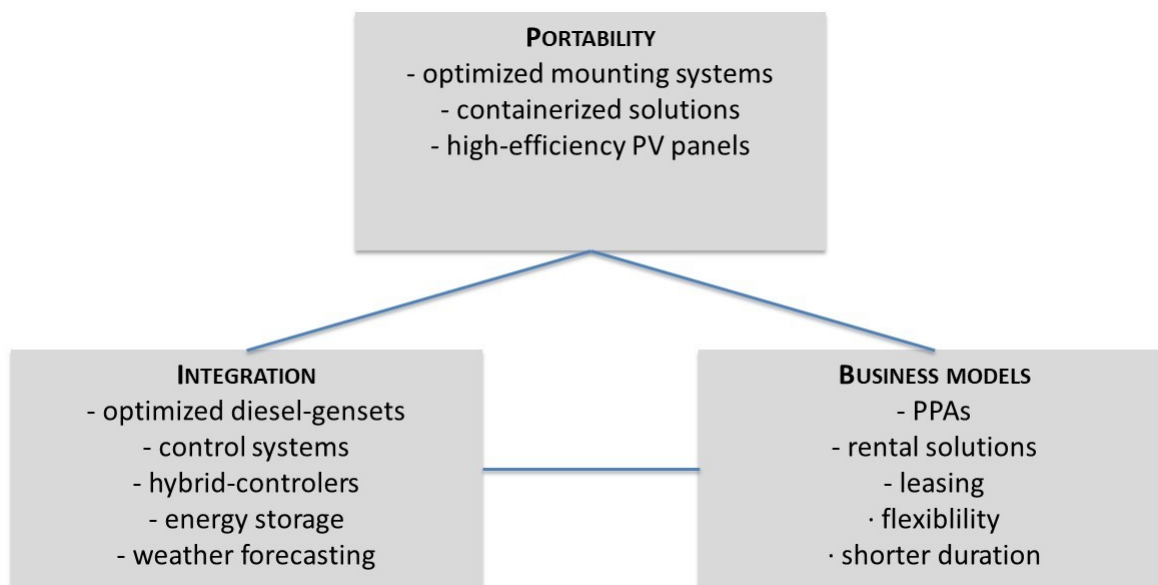


Figure 2: Different areas of improvement for hybrid systems

The portability of the solar power plants merits particular attention. While the technical lifetime of solar systems is in the range of 25 years or more, the planning horizon in mining is often significantly shorter.

### 3 Requirements for solar power plants at remote mines

#### 3.1 Ecological aspects

Mine operations are often located in remote areas that are at the same time extremely sensitive. Mining has a significant impact on the environment. There is broad agreement to minimize the environmental impact of mines. For this reason, mining also attracts broad public attention. In many countries, mining is strictly regulated. Often mines must be dismantled completely in the rehabilitation process. Renewable energy commonly is regarded as environmentally friendly per se. However, there are also some aspects that require special attention.

When solar power plants are dismantled or relocated, it depends to a large extent on the mounting systems used if significant residues remain or not. Removing concrete and ground screws can be cumbersome and costly. The building process also requires additional construction equipment which might have a negative impact on the environment. The objective is to build a solar power plant in a manner that is as environmentally friendly as possible (green in), and when removing it, the environmental footprint should also be minimized (green out). This can be achieved by using mounting systems that are environmentally friendly.

#### 3.2 Costs

Minimizing the environmental impact of mounting systems often also translates into significant cost savings. At remote installations, the use of heavy equipment is normally extremely expensive. This concerns logistical aspects for transporting the heavy equipment to the mine site.

For operating heavy equipment, normally qualified labor is needed. The same issue occurs for complicated mounting systems that are difficult to install. Qualified labor at remote locations might be an additional cost driver. Solutions that are easy to install by local workers will lead to immense cost savings. As a side-effect, the use of local labor also has a positive effect on regional development.

A minimal use of concrete and steel also has a direct effect on costs and makes solar power even less expensive.

#### 3.3 Flexibility and relocatability

##### 3.3.1 Mining exploration

Renewable energy solutions might be applied at different stages of the mining process: even at the prospecting/exploration stage. Exploration camps are small in comparison to mines in full production. Small-scale solar power plants are an excellent option for powering camps, especially as diesel is particularly expensive at these undeveloped remote locations, often without a proper transport infrastructure. Another problem arises from the need to store diesel. Sometimes diesel for remote exploration camps even has to be flown in by helicopter. This means that in these extremely remote locations every liter or gallon of replaced diesel consumption has a particularly high value.

There is another aspect that should be mentioned which used to make the use of solar to power remote exploration camps unfavorable, namely, the need to relocate the camps rather frequently. Diesel gensets and also the control equipment of solar power plants are often containerized. Relocation is cumbersome, but not a major issue. The situation used to be different for the solar array itself. For centralized solutions, solar arrays were built in such a way that the power plant remained at one location throughout its lifetime, and not too much attention has been paid to traditional mounting systems with regard to relocatability. This is particularly valid for approaches with concrete piers and steel piles. Relocatability is not only restricted by high material requirements, but also the need for construction equipment at the site. New mounting system concepts take this into account by optimizing the installation process and minimizing the

material used. At the same time, these modern solutions allow for building a solid solar system capable of withstanding the strongest climate and weather impacts.

### 3.3.2 Mining production

In the production stage, the need for relocatability is less profound. The main driver for large-scale plants is more the size and the latent risk of stranded assets. Large-scale solar plants also might have to be relocated when the lifetime of the mine has been reached.

Even for mines with expected lifetimes in the range of 25 years or more, relocatability will create additional advantages. Typically, the planning horizon is much shorter in mining. This is especially valid for power generation, often not considered as a key success factor by miners. Diesel supply contracts are seldom closed for periods of more than 5 years. Other factors are shorter mining licenses and incertitude about the size of deposits. For mining companies, it can also make sense to stop mining operations during periods when world market prices for certain commodities are particularly low and cannot cover the operating costs.

PPAs are normally 'take-or-pay'-type contracts. For IPPs, the stationarity of traditional solar power plants represents an enormous counterparty risk. If offtakers do not fulfill their payment obligations, relocatability allows for increasing the pressure on them.

## 4 Earth anchor based mounting systems meeting the requirements in mining

Earth anchor based mounting systems perfectly meet the requirements that the mining industry has regarding solar power plants. The Osprey PowerPlatform is a solar racking system that holds the solar modules using only minimal penetration foundations. At the heart of this system are so-called earth anchors.



*Image 1: Osprey PowerPlatform with earth anchors*

They have been used for a long time in a variety of applications, including conventional power generation projects and in mining, where they, for example, provide foundations for fabric buildings which are an ideal building solution that can be rapidly installed in remote areas to meet rigid construction timelines. In the innovative Osprey PowerPlatform concept, earth anchors secure the foundations of ground-mount solar arrays. Earth anchors can be deployed universally as they work in virtually any type of soil on any site, even under the most challenging of conditions, such as in desert hardpan, rocky soil, permafrost or on landfills.

Earth anchors function similarly to helical piles and ground screws with the anchor being a hot-dipped galvanized, ductile iron casting about 15 cm (5 in.) long and 4 cm (1.5 in.) in diameter. In the center is an



“eye” for attaching a stainless-steel cable or a galvanized threaded rod. At one end is a penetrating “teeth”, at the other, a hole for inserting the drive rod which is used for driving the anchor and cable into the soil. When the drive rod is removed, and uplift force is applied to the cable or rod, the underground anchor rotates into its final, horizontal and locked position.



Image 2: Example of an earth anchor

The earth anchor foundation system proves to be more universal, easier, faster and less expensive than other foundation options, from procurement through to construction and, optionally, decommissioning. With such advantages, earth anchor foundations are destined to become increasingly popular with EPCs, developers, and contractors alike for ground-mount solar projects. As the earth is not broken, the environmental impact is minimized. Earth anchors guarantee an extremely powerful fixing in the ground due to a large amount of contributing soil above due to the “inverted cone” principle (see Figure 3).<sup>1</sup>

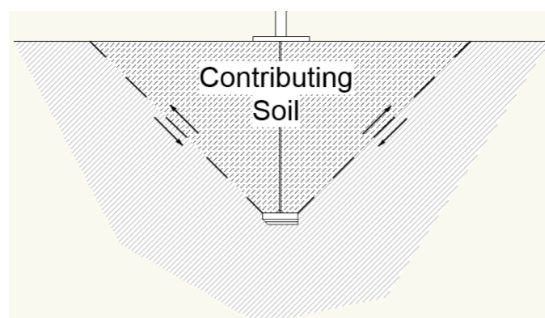


Figure 3: The concept of earth anchors<sup>2</sup>

The ease of installation and high holding power make earth anchor foundation systems suitable for sites where deploying solar power has previously been considered impractical or impossible. Nuance Energy’s Osprey PowerPlatform is suitable in the standard version for slopes up to 12° or, with custom engineering, up to 23°.

The installation begins by assembling the platform and placing it in position. The height of each anchor stand is adjusted to level the racking system as it is assembled. The only tool needed to set earth anchors

<sup>1</sup> For a description of the earth anchor concept, see also Stevens, J. (2017), Earth anchors—more than helical piles and ground screws—help make ground-mount solar more profitable, Solar Power World, <https://www.solarpowerworldonline.com/2017/08/earth-anchors-ground-mount-solar-profitable/> (accessed on 18. May 2018).

<sup>2</sup> Matthew Gilliss (2017), STRUCTURAL OVERVIEW OF EARTH ANCHORS FOR PV GROUND MOUNTED ARRAYS.



in the soil is an electric or pneumatic jack-hammer. Finally, the solar modules are installed, wired and connected to the inverters. The design of the Osprey PowerPlatform provides an integrated trough for the wiring, which eliminates the need for separate wire management channels or conduits. The design also provides a suitable structure for mounting the inverters, eliminating the need for concrete pads. A standard 16-module (2×8) array is supported by six anchor stands that distribute the total weight. For wind loads, all six earth anchors (one per stand) can secure a total uplift force of over 6000 kg, depending on depth and soil conditions. Additional anchors can be set as needed, such as with unusually high winds or poor soil conditions.

At the same time, the amount of material used is optimized: sufficient to ensure a robust and stable solar power plant even at extreme weather conditions that often are encountered at remote mining sites. Earth anchor based mounting systems use no concrete and much less steel than traditional solar PV mounting systems. The environment benefits in several ways: less resources are needed, less material must be transported to the remote sites, and when dismantling the systems, the impact is also minimized. Figure 2 shows the earth anchor concept in comparison to other foundation concepts for mounting systems.

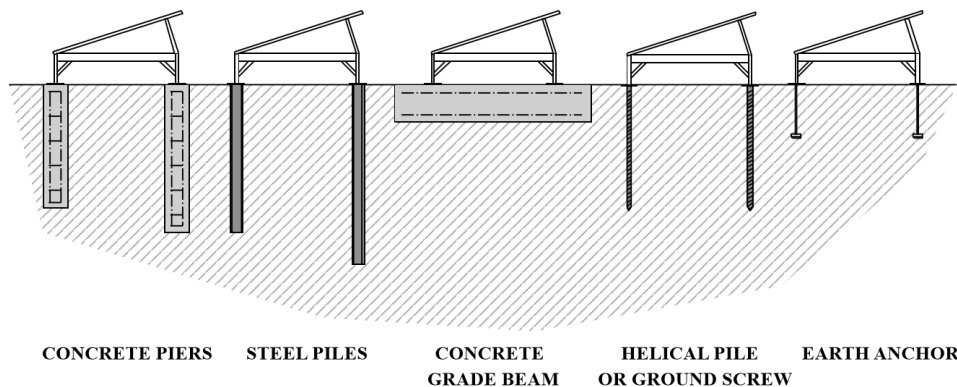


Figure 4: Comparison of different mounting system types

The optimized material use ensures also that the Osprey PowerPlatform is more cost-efficient than traditional mounting systems. Various cost-saving factors can be differentiated:

- reduced planning costs due to almost universal application
- lower direct costs for material
- improved transportation costs
- shorter installation times
- lower labor costs
- no heavy equipment needed
- ease of testing

Unlike conventional foundations, an earth anchor foundation system does not require a detailed geotechnical report or extensive engineering efforts. The planning costs can be reduced substantially.

The reduced material translates directly into cost savings and indirectly into reduced transportation costs. The simple approach minimizes installation times and does not require skilled labor. Both reduce the overall labor costs as part of the total installation costs.

A four-person crew is able to assemble a 45-kW solar array consisting of 128 350-W panels in eight hours. Another factor reducing the installation costs is the fact that no heavy equipment is needed in the installation process. The installations are done with handheld and easy-to-use power tools.

The system allows for conducting simple, inexpensive field load tests to measure the actual holding capacity of every earth anchor in real time. This eliminates the need for inspections and virtually guarantees that the required specifications and local regulations are met.

Finally, the solar power plant can be relocated more easily. The costs for moving the solar power plant are improved as the entire framework can be disassembled for use at another site. Except for the inexpensive earth anchors, nothing is left behind. This “lift and shift” portability is attractive for mining applications. The earth anchor foundation system offers this significant additional advantage over all other alternatives. Relocatability is a key requirement for using solar for powering exploration camps as well as for powering mines in the production phase – especially if third-party IPPs are involved and sell the electricity through “take-or-pay” PPAs to the mines.

## 5 Conclusions and outlook

This white paper shows that solar projects for the mining industries have special requirements. Several tailor-made solutions for off-grid solar-diesel hybrid plants have been developed recently. These solutions comprise the integration of solar energy to existing diesel power plants, local weather forecasting, and optimized diesel generators. Earth anchor based mounting systems were already used in the mining sector for providing the foundations of fabric buildings which are an ideal solution in remote areas. This concept was adopted by the solar industry and used for the foundations of PV mounting systems. Nuance Energy now takes it with its Osprey PowerPlatform platform back to the mining industry. This white paper shows that it is perfectly suited for solar applications in the mining industry as it minimizes the environmental impact of the solar power plant. Reductions in material use and lower requirements regarding transport not only have positive impacts on the environment but also reduce costs significantly. The innovative mounting system allows for further cost reductions through shorter installation times and the ability to rely on local labor. Moreover, there is no need for heavy equipment.

The approach also provides solutions to a special requirement in off-grid power generation in general and to mining in particular. The power generation asset is linked to one or only a very limited number of offtakers. If the power demand of these offtakers decreases, the solar PV plant might lose its economic basis at a certain site. In mining, this could happen when a mine is shut down at the end of its lifetime, if a mining company has to file for insolvency or in mining exploration when mining camps are relocated. The “lift and shift” portability of the Osprey PowerPlatform allows for disassembling the entire framework, which then might be used at another site. Except for the inexpensive earth anchors, nothing is left behind. This feature makes the mounting system extremely attractive for all kinds of off-grid solutions.

These advantages, in combination with the fact that the solution is already used in mining for fabric buildings, make the innovative approach a perfect fit to the miner’s needs regarding optimizing environmental impact, costs, and robustness of a solar solution. It also allows for building solar power plants in harsh environments where traditional solutions cannot be applied. Earth anchor based mounting systems are another piece of the puzzle that will make solar more attractive to mining companies.

## About Nuance Energy

Nuance Energy is making solar energy substantially more affordable. The company's patent- pending Osprey PowerPlatform® solar ground mount racking system employs a unique earth anchor and modular, scalable design to enable contractors, integrators and EPCs to achieve peak profitability through the industry's lowest installation costs and fastest time-to- revenue for ground mounted systems. Nuance Energy's mission is to lead solar innovation while focused on the solar industry's downstream value chain saving partners and customers time and money. Headquartered in San Ramon, CA, Nuance Energy ([www.nuanceenergy.com](http://www.nuanceenergy.com)) and its subsidiary AgWell Solar ([www.agwellsolar.com](http://www.agwellsolar.com)) provide design, engineering, installation and financing for select projects.

## About THEnergy

THEnergy is a boutique consultancy founded in 2013 focusing on microgrids/mini-grids and offgrid renewable energy. For industrial companies, THEnergy develops energy concepts and shows how to become more sustainable – combining experience from conventional and renewable energy with industry knowledge in consulting. THEnergy also advises investors and energy companies regarding renewable energy opportunities in rapidly changing markets. The initial focus was on commercial and industrial offgrid renewable energy projects, for example in mining ([th-energy.net/mining](http://th-energy.net/mining)), hospitality, telecommunications or on islands ([th-energy.net/islands](http://th-energy.net/islands)). Driven by investor needs, rural electrification and energy access have become additional consulting focusses. THEnergy has lead several large-scale due diligence processes in rural electrification.

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