

# Powering the future

Innovative solutions for  
renewable energy



# A revolution in energy

Innovation lies at the heart of the renewable energy revolution, making different sources cheaper and more efficient. Technology is changing all the time. The wind sector illustrates this. Turbines are getting bigger, particularly offshore, as well as more aerodynamic.

Over the past 20 years, rotors have increased from about 150 feet (46 meters) in diameter to 400 feet (122 meters), while towers are often nearly 300 feet (90 meters) above sea level. The larger the diameter, the greater the area that can be swept, and taller towers catch the faster-blowing winds at higher altitudes.





More powerful and efficient turbines are helping to bring down the price, and this is expected to continue. In 2017, Bloomberg New Energy forecast that the levelized cost of offshore wind — the unit cost of electricity over the lifetime of a generating asset — will decline 71% by 2040, while the cost of onshore wind will fall over the same period by 47%, on top of the 30% drop of the past eight years.

Innovation is key to reducing the cost of renewables and ensuring grid resilience as the conventional centralized system of generation disappears. We have worked on innovative projects to incorporate energy storage to maximize energy yield, provide energy security, limit variability of output to the grid, and provide ancillary services to the network operator.





# Helping to spark change

Renewable energy capacity across the world is growing exponentially. According to the International Renewable Energy Agency, a further 167 gigawatts of renewable power was installed worldwide in 2017, up from 164 gigawatts in 2016 and 157 gigawatts in 2015 — the third consecutive year that more renewable than conventional energy capacity was added.

We have extensive experience in renewable power at Mott MacDonald. Globally, over the past 10 years we have provided engineering services for 30 gigawatts of hydropower, 80 gigawatts of wind, 17 gigawatts of solar photovoltaic (PV), 6 gigawatts of concentrated solar power (CSP), and 12 gigawatts of geothermal capacity.

Our energy expertise goes back a long way. From Sir Murdoch MacDonald's work on the Aswan Dam in Egypt, our engineers have been working for more than 100 years to help deliver power to people and communities. We have worked on many landmark power projects across the world, covering a range of technologies, often with technical challenges requiring novel solutions as "firsts" in the industry. It is a proud heritage and one we strive constantly to continue.



Over the last 10 years we  
have helped deliver

30GW	80GW	23GW
hydropower	wind	solar

We are a connected business, meaning we are joined up across sectors and geographies. This gives clients access to exceptional breadth and depth of expertise. Often input from specialists in supporting infrastructure is as important as energy expertise and financial acumen in delivering a successful project.

Meanwhile, our extensive capability in transmission and distribution, including high-voltage direct current (HVDC) and undersea cabling, ensures the power from renewables is moved from where it is generated to where it is needed, and that operators everywhere can meet the challenge of balancing a grid reliant on renewables and meeting peak demand.

# United States

Delivering solutions for America's first offshore wind farm



Around the world, 65 offshore wind farms have been created with Mott MacDonald's participation.

### Opportunity

In the summer of 2016, a state-of-the-art jackup vessel traveled from France to Rhode Island, carrying five nacelles for the Block Island Wind Farm. The first project of its kind in the US, the wind farm would generate enough power for more than 17,000 homes.

### Solution

During the course of the project, Mott MacDonald provided owner's engineering services to Deepwater Wind, including feasibility studies, conceptual design, cost estimates, permitting, and public relations.

### Outcome

The Block Island Wind Farm began operations in December 2016. According to the *New York Times*, many people hope this marks "the start of a new American industry, one that could eventually make a huge contribution to reducing the nation's climate-changing pollution." The *Times* noted that nearly two dozen offshore wind farms are on the drawing board.

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### Project

Block Island Wind Farm

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### Location

Block Island, Rhode Island

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### Client

Deepwater Wind

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### Expertise

Owner's engineering services

Enough electricity to power

# 17,000 homes



# Tapping the energy of the world's largest solar thermal plant



Mott MacDonald helped deliver electricity from the desert to thousands of homes and businesses.



**Project**

Ivanpah Solar Electric  
Generating Facility

**Location**

Ivanpah Dry Lake, California

**Client**

Klondyke Construction

**Expertise**

Engineering and design

173,500  
heliostats

377  
megawatts

**Opportunity**

Constructed in California’s Mojave Desert, the Ivanpah Solar Electric Generating Facility is the world’s biggest solar thermal plant. A total of 173,500 heliostats, each equipped with two mirrors, focus the sun’s energy on water tanks mounted at the top of three towers.

**Solution**

Mott MacDonald provided engineering and design services for 33- and 115-kilovolt underground and overhead transmission lines. We designed interconnections between the three solar plant blocks and Southern California Edison.

Underground transmission included 2.5 circuit miles (4 kilometers) of buried cable. Overhead transmission included two miles (3.2 kilometers) of conductors supported by 39 steel poles, typically 70 feet (21 meters) tall. We used PLS-CADD software to model the transmission lines.

**Outcome**

With a net output of 377 megawatts, Ivanpah produces enough power to supply 140,000 homes during peak hours of the day. The complex reduces CO<sub>2</sub> emissions by an estimated 400,000 tons per year.



## Fast-start station to balance troughs in wind energy supply

# 800MW

gas-fired power plant

# 3,000

wind turbines

### Opportunity

Gemma Power Systems operates a cluster of 3,000 wind turbines in the arid California desert. However, the facility needs supplemental power to balance out troughs in the supply of wind energy, and to meet peak demand in the summer.

### Solution

Mott MacDonald provided the complete design and engineering for an 800-megawatt simple-cycle gas-fired power plant, plus a 12-breaker 230-kilovolt switchyard and interconnection with Southern California Edison.

The project featured eight “aeroderivative” gas turbines.

Our mechanical engineering team prepared general arrangement drawings, piping and instrumentation diagrams, piping drawings, and equipment specifications. Major mechanical systems included gas turbines with evaporative cooling, selective catalytic reduction (SCR), gas compressors, zero-discharge wastewater system, fire protection, and a demineralized water system. The design was generated with our 3D design package.

### Outcome

The plant uses eight aeroderivative turbines, like those used in aircraft and ships. Lighter and faster-starting than industrial turbines, they enable the plant to go from initiating a full combustion turbine generator (CTG) start to full load in just ten minutes. The turbines also provide flexibility, as the plant must be able to vary its production between 50 and 800 megawatts.

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### Project

Sentinel energy project

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### Location

Palm Desert, California

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### Client

Gemma Power Systems

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### Expertise

Detailed engineering and design with field support



# Making connections in the desert

## Opportunity

The Iron Horse project consisted of a two-megawatt PV solar farm and a ten-megawatt energy storage system. The client required a single point of interconnection that would protect both systems and coordinate them with the local utility.

## Solution

We worked with all stakeholders, including equipment vendors, general contractor, owner, grid operator, and transmission reliability operator, to design a medium-voltage outdoor switchgear assembly with integrated protection and control equipment.

## Outcome

As part of a collaborative engineering, procurement, and construction team, we helped to provide jobs, investment, and renewable energy for Arizona.

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## Project

Iron Horse PV solar and energy storage

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## Location

Pima County, Arizona

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## Client

Westwood Professional Services

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## Expertise

Switchgear design, protection and control design, protection coordination, system studies



# Latin America

Milestone onshore  
wind projects

## 550MW

onshore wind plans in Argentina

## 442MW

Reynosas wind farm in Mexico

## 270MW

Penonomé plant, Panama's first wind farm



Over the past decade, we have been involved in about 50 onshore wind projects across Latin America, as an advisor to investors and as owner's engineer to support the development of wind farms.

### Opportunity

The largest markets in Latin America for onshore wind projects are currently Argentina, Brazil, Chile, and Mexico. Restructuring of the energy market in Mexico has prompted energy companies to invest, and the government has plans for significant wind and solar generation. Argentina recently launched a tender for 550 megawatts of onshore wind as part of its program to lift the proportion of electricity generated by renewable sources to 20% by 2025.

### Solution

Our work across Latin America is predominantly as lenders' engineer, which involves assessing a project against technical, environmental, and safety criteria, and producing a report for investors to inform their decision-making. We also work as owner's engineer on around 20% of the projects for which we are the lenders' engineer.

A specialized team that focuses on the Latin American wind market is based in our Houston office, supported by offices in Brazil and Colombia. This enables our team to better understand the needs of clients and stakeholders, and to provide advice about electrical grid and environmental aspects of power projects. Our local presence has also strengthened our relationship with commercial and development banks and export credit agencies in the region and globally.

Since 2010, we have worked on projects in the region worth about \$10 billion. These include the 50-megawatt Orosi wind farm in Costa Rica, which in 2013 won *Project Finance* magazine's award for best Latin America wind deal. We worked as lenders' engineer for the 270-megawatt Penonomé plant, Panama's first wind farm, and we are working as technical advisor on the financing of ten projects in Uruguay.

We acted as lenders' engineer for Cerro de Hula in Honduras, one of the first large wind projects in Latin America. We carried out a comprehensive review, including designs, energy yield, contracts, construction and operational methodology, environmental and social assessment, and technical inputs to the financial model.

### Outcome

We are currently working on the 442-megawatt Parque Eólico Reynosa wind farm. With 123 wind turbine generators, this will be Mexico's largest wind farm and one of the largest in Latin America. It will provide energy to approximately 900,000 people and avoid the emission of 739,000 metric tons of carbon each year. The wind farm will also help Mexico reach its overall target of generating half its electricity from clean energy sources by 2050.

# United Kingdom

## Tidal turbines with multiple added benefits

# 1.5 million

homes with power

A tidal energy project in northwest England could transform the region's energy profile, improve transport links and flood defenses, and boost job creation.





### Opportunity

The Northern Tidal Power Gateways project aims to ease traffic while generating more than 6,500 gigawatt-hours per year: enough to power more than 1.5 million homes. A divided highway will connect the M6 highway in the south with Millom in the north, while breakwaters at Morecambe Bay and the Duddon Estuary will incorporate tidal turbines.

The sheer scale of the project is demanding. Based on current capacity, it would take the entire world's hydro turbine manufacturing resources to produce the 132 machines required. There are also technical challenges in terms of connecting a large number of intermittent machines to the grid.

The location is environmentally sensitive, with the bay and estuary jointly designated as a Special Protection Area. Past projects have changed the range of the intertidal zone, which is crucial to maintaining local ecosystems. The variable-speed turbines used for Northern Tidal Power Gateways can pump and generate energy in two directions, reducing flood risk, mitigating sea-level rise, and maintaining the stability of the habitat.

### Project

Northern Tidal Power Gateways

### Location

Northwest England

### Client

Northern Tidal Power Gateways Ltd.

### Expertise

Advisory services

### Solution

The project is in the scoping stage, and we have undertaken multiple studies across a myriad of disciplines to assess potential energy generation, road users, revenue, and environmental constraints and benefits. The aim is for construction to begin in 2024, with Duddon Estuary producing power by 2027 and the project completed in 2031.

### Outcome

Combined benefits from increased employment, improved connectivity, economic growth, flood control and protection, and an enhanced environment have been estimated at more than \$1.1 billion (£1 billion) per year. The divided highway could cut travel times across the industrial hub of Barrow-in-Furness from two hours to 25 minutes.

Estimates indicate that the project will generate more than 7,500 building jobs and contribute more than \$340 million (£300 million) gross value added per year to the region's economy during construction.

**6,500GWh**  
of electricity

The Gemini project was one of the largest such projects in the world to be project-financed.



# The Netherlands

## Reaching financial close on a 600-megawatt offshore wind farm

### Opportunity

The \$3.2 billion (€2.8 billion) Gemini project was the largest offshore wind project to reach financial close when backing was secured in 2014. Financiers' main concern was that long-term production would be lower than forecast or, in a worse-case scenario, the project would not go ahead. Sixteen banks and financial institutions were involved.

Environmental concerns, such as protecting sea mammals from the noise of driving monopile foundations into the seabed, was another challenge.

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**Project**Gemini Wind Park

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**Location**Netherlands

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**Client**Gemini Wind Park

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**Expertise**Lenders' technical  
advisor, engineer

# 1.25 million

metric tons of carbon savings a year

# 600MW

capacity

**Solution**

As lenders' engineer, our role was to advise banks on the technical risks of the project, and what sort of mitigation could be put in place in terms of health and safety, design, manufacturing, and the environment.

Organization, communication, and a consistent approach to managing information were key to keeping track of the large number of queries and responses flowing between us and the investors. After financial close, our role moved to monitoring construction, providing monthly progress reports to the financial backers.

Our project team scrutinized objectives, processes, and strategies to deliver Gemini over the two-year construction period. We were part of ongoing discussions during the construction phase.

Spotters on boats ensured the area was clear of whales and dolphins before work started. After the "all clear" was sounded, a technique known as "soft starting" was used, where pile driving begins gently and then increases to the required force.

The last 9 miles (15 kilometers) of the twin 53-mile (85-kilometer) export cables could only be installed when the tide was out. A vehicle plowed a channel in the sea bed while laying the cable from a reel mounted on its roof.

**Outcome**

The wind farm was completed ahead of schedule and under budget in April 2017. Comprising 150 Siemens turbines, each with 4-megawatt capacity, it features two offshore high-voltage substations and a pair of 220-kilovolt cables that transport the energy more than 53 miles (85 kilometers) to the coast at Eemshaven.

The project provides energy to approximately 785,000 households and is helping the Netherlands meet its target of 14% renewable energy generation by 2020. It will also cut carbon emissions by 1.25 million metric tons each year.



# Cyprus

## A strategy for a new electricity market

# 16%

renewable energy  
target for Cyprus

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### Project

Strategic Energy Planning

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### Location

Cyprus

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### Client

Electricity Authority of Cyprus

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### Expertise

Modeling and analysis



### Opportunity

The Electricity Authority of Cyprus is currently the sole provider of electricity in Cyprus, but the government is opening up the market to new participants to comply with European Union (EU) rules.

Cyprus plans to move away from its reliance on imported heavy fuel oil and invest in infrastructure that will allow the introduction of natural gas. The island must also achieve an EU target for 16% of its energy to come from renewable sources by 2020.



Sophisticated modeling is helping Cyprus to develop new energy strategies.

### Solution

Our energy advisory team is supporting the Authority with decisions about existing and new energy plants. The modeling tool PLEXOS helps us take account of several complexities. PLEXOS was used to develop a set of strategies for the company, based on the availability of natural gas and timing of electricity market reform.

To remain competitive when the energy market opens, the Authority must become even more cost-effective. Our energy model is flexible enough to deal with the uncertainties around fuel availability, market conditions, and varying levels of renewable generation.

Cyprus has significant solar resource, but we had to consider the impact of intermittency, how much reserve capacity was needed to ensure smooth system operation, and whether installing battery storage was necessary. PLEXOS was also used to optimize maintenance scheduling and to estimate fuel consumption and carbon emissions.

### Outcome

We created many future scenarios, modeled and analyzed them, and compared the results. This enabled us to develop investment strategies for the Authority. Our combined expertise in engineering and modeling enabled us to demonstrate what was technically and economically feasible.

# South Africa

## Innovation in concentrated solar power

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### Project

KaXu Solar One

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### Location

Northern Cape, South Africa

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### Client

Abengoa

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### Expertise

Lenders' technical advisor



Advances in technology have enabled concentrated solar power (CSP) projects in South Africa to add energy storage, extending power availability hours into the night.

### Opportunity

A typical dilemma faced by solar power developers is that demand tends to peak at sunset when the sun's energy is fading. Concentrated solar power (CSP) offers a solution.

One type of CSP uses parabolic mirrors to focus the sun's energy and heat fluid in tubes. The fluid passes through heat exchangers, where it generates steam that turns a turbine to generate power. To store the energy, the fluid heats a reservoir of molten salt to 725°F (385°C). The salt gradually releases the energy to keep power production going after sunset.

In South Africa, investor support for this innovative technology was not immediately forthcoming. Lenders were initially apprehensive, and with no precedent it was hard to conduct due diligence.

# 100MW

KaXu Solar One

# 50MW

Khi Solar One

# 100MW

Xina Solar One

### Solution

As the lenders' technical advisor for the 100-megawatt KaXu Solar One plant in the Northern Cape, we were directly involved in contract negotiations on a daily basis. We accompanied the lenders to Spain to see how the developer's pilot plant worked and provided examples of where equipment used in these projects is already in operation in thermal plants.

Confidence in the technology soared through this project, paving the way for the development of the more advanced 100-megawatt Xina Solar One plant. This plant uses molten salt to provide a five-hour thermal energy storage system. It features the largest parabolic trough collector used in a commercial CSP project to date, and benefits from the country's "time of day" payment structure, which incentivizes generation during peak demand hours.

We also worked on the 50-megawatt Khi Solar One plant, operational since the beginning of 2016, and are currently involved in all seven CSP projects awarded under South Africa's renewables program.

### Outcome

The KaXu Solar One project began operation in 2015 as the first large-scale CSP plant with storage developed by the private sector in an emerging market. The project has stimulated local economic growth and created jobs in the Northern Cape, an impoverished province with one of the highest youth unemployment rates in the world.

KaXu Solar One has also brought social benefits. The local community has a minority share in the project, so it directly supports long-term education and economic development initiatives in the area. The project has contributed to the creation of a local supply chain, generating both skilled and unskilled jobs.



# Tanzania

## Capacity building for geothermal development

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### Project

Customized Training Program

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### Location

Tanzania

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### Client

Tanzania Geothermal  
Development Company

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### Expertise

Assessment and capacity building



### Opportunity

Tanzania's location in Africa's Rift Valley gives it rich potential for geothermal energy. The successful development of geothermal plants in neighboring Kenya has spurred Tanzania to explore its own opportunities.

The government established the Tanzania Geothermal Development Company (TGDC) to spearhead new projects. Exploratory drilling and initial studies in Ngozi, in southwest Tanzania, have shown the site could produce 200 megawatts of energy.

To investigate the full potential of geothermal energy, TGDC requires financial support from institutions such as the World Bank and African Development Bank. Each bank has its own environmental and social impact assessment (ESIA) standards that must be followed to obtain funding.



The development of geothermal plants can alleviate Tanzania's frequent blackouts while aiding sustainable development and reducing poverty.

### Solution

The World Bank appointed us to assess and build capacity within TGDC to enable it to meet the required ESIA standards. We also trained staff from state-owned electricity supplier TANESCO, the Ministry of Energy and Minerals, and the National Environment Management Council, which are responsible for granting permits for the environmental process.

We prepared a customized training program that covered all environmental and social aspects of a geothermal project, from air quality and biodiversity to indigenous people and cultural heritage. We explained how all these issues should be reflected in project design, and how Tanzania's impact assessment processes differed from the international ESIA approach.

Our team briefed trainees on how to respond to questions and possible audience behavior. Trainees prepared responses to questions likely to be raised, and they took part in a role-play exercise, acting as representatives of the local government, a small business owner, farmers, and environmental activists. Excellent feedback was received from participants, particularly on how topics were taught and the interactive nature of the training.



### Outcome

Our work contributed significantly to TGDC's capability to assess, address, and manage environmental and social risks and impacts, and helped to identify appropriate, project-specific mitigation and opportunities for enhancing environmental and social benefits in line with international good practice.

The increased capacity will go beyond benefiting the Ngozi project and contribute to the sustainable development of similar future projects in TGDC's pipeline.



The Suki Kinari hydropower plant will be powered by the Kunhar River, which traverses the length of Pakistan.

# Pakistan

Hydropower high  
in the Himalayas

# 870MW

installed capacity

# 3,050GWh

annual energy generation

## Opportunity

Located in the Kaghan Valley, high in the Himalayan mountains, the Suki Kinari hydropower plant is urgently needed, as Pakistan suffers frequent power cuts.

The plant has a run-of-river design and enough active reservoir volume to generate four hours of peak power. This lowers the capital cost and minimizes environmental impacts. There will be a height difference of more than 2,950 feet (900 meters) between the head of the dam and the powerhouse, enabling the plant to produce 870 megawatts.

The complex geology of the area, a seismic zone with active faults, is the biggest challenge to the project. Construction has to take account of very low winter temperatures, with snow and poor road conditions halting construction of the dam during the winter months.

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## Project

Suki Kinari Hydropower Plant

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## Location

Pakistan

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## Client

SK Hydro Consortium

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## Expertise

Owner's engineer

## Solution

We have been involved in the project since 2008, conducting an initial feasibility study. We are now working as owner's engineer for the developer SK Hydro Consortium, a role that involves reviewing the design, construction supervision, and project management. The project achieved financial close in 2016.

Detailed design and construction are being carried out in tandem, allowing design changes to be made when necessary.

## Outcome

The dam was originally designed with an asphalt face to make it watertight. The asphalt layer was instead placed inside the core of the dam, significantly improving its ability to deal with extreme temperatures at the location, which can go as low as -4°F (-20°C). The location of the underground powerhouse was moved closer to the river, requiring an access tunnel only 2,300 feet (700 meters) long rather than 2.5 miles (4 kilometers) in the original design.

Suki Kinari will provide peak power, so it can be mobilized when needed to help stabilize the grid. It is scheduled to start generating power at the end of 2022.



# Japan

## Large-scale solar electricity from a former salt field



Setouchi Kirei is one of the largest solar PV projects in Japan. The billion-dollar project is located on a former salt field near the city of Setouchi in southern Okayama Prefecture.

# 900,000

PV modules

# 235MW

capacity

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## Project

Setouchi Kirei

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## Location

Setouchi, Japan

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## Client

Setouchi Kirei Future Creations

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## Expertise

Owner's engineer

### Opportunity

Covering about 1,235 acres (500 hectares), the former Kinkai salt field is located in an area of strong sunlight, mild climate, and a low risk of natural disasters: all factors that make it a promising location for a photovoltaic (PV) facility.

One challenge was to get an accurate estimate of available solar irradiance. Another was to safeguard a nature conservation area within the site, including a breeding ground for the rare Eastern Marsh Harrier.

### Solution

We acted as owner's engineer during the development phase of the project for the developer, Setouchi Kirei Future Creations. The role involved assessing plant performance and drafting plant test procedures, supporting contract negotiations, and advising on procurement.

We introduced a new way of improving the accuracy of irradiance estimates, and got the backing of investors for our approach. This involved using data from the local weather station to correct satellite information to estimate long-term irradiance.

Since utility-scale PV plants were uncommon in Japan, the team used international standards in drafting contracts for engineering, procurement, and construction, as well as for contractors' handling operations and maintenance. Persuading the client and contractors to accept international standards involved discussions and negotiations on PV module testing procedures, contracts, and procurement.

### Outcome

Our multidisciplinary team is currently managing the construction schedule and supervising building quality at the plant, and for the transmission line and a reinforced sea wall on the coastal side of the site, designed to prevent flooding. The plant will comprise more than 900,000 PV modules and is expected to begin operations in 2019. Construction was scheduled to avoid the breeding times of the Eastern Marsh Harrier.

According to Akinari Takehisa, mayor of Setouchi City, "Kinkai Salt Field, owned by Setouchi City, used to be the largest salt field site in East Asia. Now the site is about to be reborn as a new base which will provide clean energy as one of the biggest solar power plants, protect citizens from disasters with safety and security, and contribute to community development through land lease income. My hope is that these projects will give dreams and hopes to children and help Setouchi City to continuously shine as 'Town of the Sun.'"

Opening opportunities with connected thinking.

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