RE-SAT: Energy Analytics Platform

# Renewable Energy planning in Montserrat

## Case study

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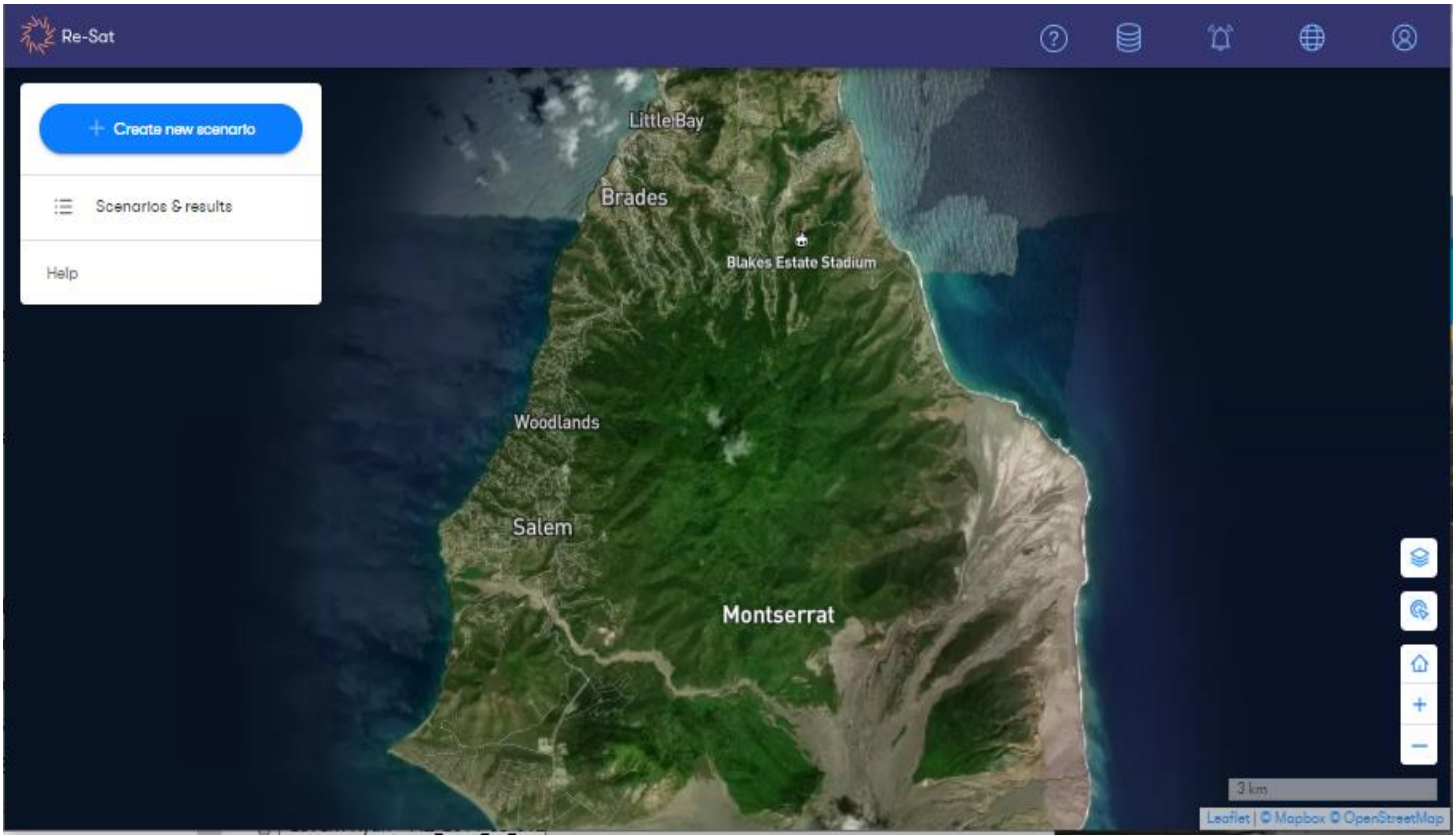


## The Institute for Environmental Analytics (IEA)

Founded in 2015, the Institute for Environmental Analytics (IEA) is a research and development centre for big data analytics in the environmental field. The IEA specialises in turning large scale, global environmental data into easy-to-use products for clients in the energy, agriculture and infrastructure markets.

## Energy Analytics Platform

RE-SAT is a new, cloud-based energy analytics platform that focus on the pre-feasibility and strategic planning of new renewable energy infrastructure, from single project development through to national energy transition strategies. The platform fuses satellite and in-situ weather data with advanced analytics to provide highly detailed renewable energy information to help users:

- Explore and define the best renewable energy installation mix and their locations.
- Assess the potential financial viability of renewable energy investments.
- Estimate power production and variability, considering seasonal weather patterns.

The RE-SAT project is led by the IEA and funded by the UK Space Agency (UKSA) International Partnership Programme (IPP). RE-SAT Phase 1 (Dec 2016 – Nov 2017) was implemented in partnership with the Government of Seychelles. Phase 2 (Jan 2018 – Nov 2021) has scaled the RE-SAT platform to 6 other Small Islands States to support their transition from fossil fuel electricity generation to renewables. The platform is now operational and ready for its commercial Phase.

## The UK Space Agency
## International Partnership Programme

The International Partnership Programme (IPP) is a 5-year, £152 million programme run by the UK Space Agency. IPP seeks to use space solutions to make a positive and practical impact on the lives of those living in emerging and developing economies through partnerships with end users in the target countries to increase their capacity and respond to specific challenges. IPP is part of and is funded from the UK Department for Business, Energy and Industrial Strategy's (BEIS) Global Challenges Research Fund (GCRF).

## Acknowledgments

The RE-SAT project (Phase 2) in Montserrat acknowledges the invaluable assistance from the Montserrat Ministry for Communications, Work, Energy and Labour (MCWEL), the GIS unit at the Ministry of Agriculture, Trade, Lands, Housing and the Environment; the Montserrat Utilities Limited (MUL), and the Statistics Department.

# Contents

# 1. Executive summary

Small Island Developing States (SIDS) are heavily dependent on expensive, vulnerable, petroleum-based power generation and can spend 15-20% of disposable income on electricity (versus 5-10% in the OECD). Whilst having abundant renewable energy (RE) resources ranging from solar and wind to geothermal and hydro, the current level of installed renewable capacity is low.

To support the planning and development of renewable energy projects, the Institute for Environmental Analytics (IEA) was awarded a grant from the UK Space Agency International Partnership Programme to develop an energy analytics platform (RE-SAT) with associated data products and modelling to support SIDS to plan and undertake their transition from fossil fuel electricity generation to renewables.

Phase 1 (2017) of the project developed a proof-of-concept platform for Seychelles, with Phase 2 (2018 – 2021) scaling the concept to 6 other SIDS and operationalising the platform ready for commercial exploitation after the end of the funded phases.

Through a collaborative process of co-creation with our country partners, the RE-SAT platform was tailored for Montserrat under three categories of development:

1) **Data and modelling:**
   a. Tailored weather data to drive the power calculations in RE-SAT. These are high-resolution multi-year simulations of key weather variables creating using modelling techniques combined with satellite[1] and in-situ data.
   b. Resource maps as a guide to the abundance of energy available for a particular type of RE installation by location.
   c. Geographical information maps to assess, in combination with the resource maps, suitable locations for renewable energy installations.
2) **Platform capabilities and features:**
   a. Variable Renewable Energy (VRE) simulation - RE-SAT models the energy generated and its variability from a combination of VRE installations (wind, solar and wave) (renewable energy scenario) as specified by the user in the platform. The power contributions from hydro, geothermal and biofuels can also be added if required.
   b. Demand comparison - If the demand for electricity is added, RE-SAT compares the RE generated by the combination of installations (the scenario) versus the demand, giving an indication of the amount of energy that still needs to be generated by other sources to meet demand and help with future energy planning.
   c. Financial analysis - RE-SAT performs a levelized cost of renewable energy calculation to assess the relative cost of one technology of combination of technologies versus another.
   d. CO2 and fuel saved – RE-SAT calculates the CO2 saved and amount fossil-fuel displaced (and related costs) by the modelled RE installation.

[1] Satellite data is being used to enhance our estimates of Global Horizontal Irradiance (GHI). Surface radiation products from: OSI-SAF (Meteosat and GOES-East) and JAXA (Himawari 8) are used as RE-SAT's primary source of data for the estimation of solar power production.

3) **Capacity building**:
   a. Working Group meetings and Training Workshops to explain the data and gather feedback on the platform – A two-way exchange of expertise and data was essential for the development of the project.
   b. Data repository – The RE-SAT platform includes a repository which contains all the data developed with the partner country for easy access and collaboration.
   c. Technical Manual – A comprehensive online Technical Manual is available from the RE-SAT platform with step-by-step explanations of how to use RE-SAT.

Our **partnership in Montserrat** was led by the Energy Unit at the Ministry for Communications, Work, Energy and Labour (MCWEL). Other government departments involved: Montserrat Utilities Limited, Statistics Department, Physical Planning unit at the Ministry of Agriculture, Trades, Lands, Housing, and the Environment and the Department of Information, Technology and eGov Services (DITES).

During the 4-year project, the platform continued to evolve in response to user requirements and feedback. The **commercial ready platform** (version 2) was successfully launched in Montserrat in June 2021 during our final training workshop (due to the pandemic this took place online). A session to discuss the way forward of how the platform would be made available to Montserrat after the funded project ends was also included.

The **performance of the RE-SAT platform in Montserrat** was tested against actual power produced by a solar PV arrays installed in some government buildings in Brades. The errors, expressed as a percentage of the installed capacity) measured on the 15-minute average power accounted to 8% and when averaging over a day the error is reduced to 2%.

A significant **early impact** that RE-SAT has had in Montserrat include:
1. The development of a wind resource evaluation to explore the potential for wind.
2. The exploration of potential scenarios to achieve 100% renewable penetration and testing the results from an Integrated Resource Plan conducted by external consultants.

Based on stakeholder feedback, the **benefit and value** that RE-SAT is adding include:
- Improved accuracy of data for decisions about the energy mix, required grid infrastructure and battery sizing – leading to potential government savings on infrastructure costs.
- Better power estimation for a mix of RE developments based on robust data – leading to investor confidence and a greater likelihood that RE investments occur, thus reducing reliance on imported (and expensive) fossil fuels.
- Appropriate RE technology capacity building – leading to partners being better equipped to plan their future RE infrastructure.

*"We have used the RE-SAT platform to actually do a desktop wind study and that helped to inform the information we used for the Energy Task Force. Looking at how we, as an island, implement different technologies it is useful, very valuable." Kenrick Burke, Director of Energy (MCWEL)*

*"I benefited exponentially from your workshops and training sessions." Oswen Carty, Energy Officer (MCWEL)*

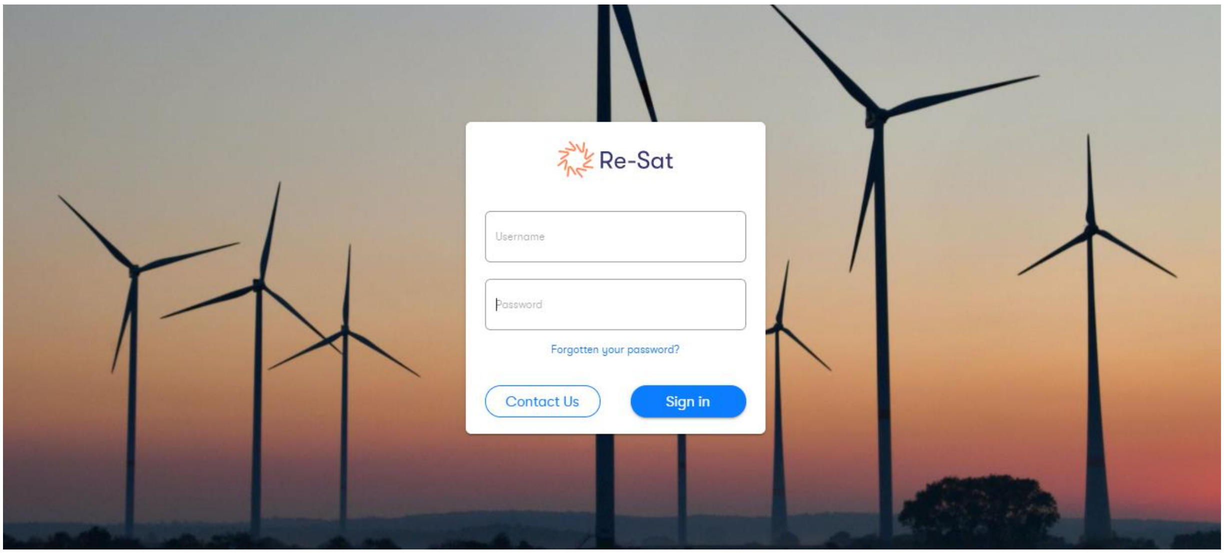



*Figure 1: Landing page of the RE-SAT platform.*

# 2. Project overview

## 2.1. The energy and data challenges facing Montserrat

### 2.1.1. About Montserrat

Monserrat is a British Overseas Territory in the northern half of the Lesser Antilles part of the Leeward Islands. The population of Montserrat is around 5,215 inhabitants, with a total land area of 102 $km^2$.

Several natural disasters have, in the recent past, caused major disruption to the development of Montserrat. In September 1989, Hurricane Hugo destroyed almost all the buildings on the island, which took several years to recover from. But in 1995, the Soufriere volcano, which is situated in the southern part of the island, started to erupt and by 1997 the eruptions had destroyed the capital Plymouth with all its government buildings, infrastructure, water and power provision.

The volcanic activity lasted until 2003. The population fell from an estimate of around 13,000 before the eruption to the current estimate of around 5,000. Two thirds of the islands are part of the exclusion zone, in which permanent habitation is not allowed and access is restricted (Figure 2).


*Figure 2: Map of Montserrat. The red line divides the island into the habitable North and the inhabited part after the volcanic activity (the Exclusion Zone).*

### 2.1.2. Electricity in Montserrat – Energy targets

As at 2021, Montserrat relies on diesel for 96.7% of its electricity generation needs, with 3.3 % generated by the 250kW solar system installed on the rooftops of the Montobacco Building, PWD Workshop and the Brade power stations. With the newly commissioned 750kW Solar PV Farm at the Look Out, it is anticipated that 12 to 14 % of the electricity generated on island will come from solar. These systems will integrate with the current MUL generating assets of 4 high-speed diesel generators with an installed capacity of 4.5MW and a 1.5MW medium–speed diesel generator.

***Figure 3**: The 250kW Solar PV systems installed in Montserrat.*

***Figure 4**: The 750kW Solar PV project under construction at the Look Out.*

The price of electricity in Montserrat is around XCD 1.00 (USD 0.37) per kWh, which is among the highest in the Region (MUL personal communication). A significant portion of the cost can be attributed to the fuel surcharges of around XCD 0.50 (18.5 cents USD) per kWh, which – even in the current period of "low" global oil prices – constitute half of the charges (MUL personal communication). The importation of expensive diesel for power generation is causing high electricity bills, increasing the overall cost of living to Montserratians and reducing the attraction of Montserrat to energy-intensive sectors[2]. In common with many Small Island States, Montserrat is: (i) economically remote; (ii) import-dependant; (iii) dependant on tourism; (iv) reliant on overseas aid; and (v) vulnerable to the impacts of climate change.

As a result, the Government of Montserrat's policy is to provide reliable, low-cost sustainable energy services through energy efficiency, and the strategic substitution of imported fossil fuels with domestic renewable energy sources. A top priority for the government is to minimize the total system costs of electricity throughout the island's transition to 100 percent renewable energy.

### 2.1.3. Challenges in renewable energy planning - common to Small Island States

Planning and managing renewable energy production require a good understanding of the variability in the natural phenomena such as clouds, wind, wave etc. In SIDS, there are a limited number of weather stations to understand significant geographic variability and records may be interrupted by operational disturbances leading to missing periods of data. These may be supplemented from time to time by specific site surveys or research projects, however these will be limited in location or timeframe.

Satellite based measurements can be used to generate data products that can regularly estimate weather parameters over large areas. However, the spatial resolution (typically in the order of kilometres) and time resolution may not always be suitable for renewable energy planning.

A key consideration in renewable energy planning and management is the need to anticipate short period (within 10 minute) fluctuations in production, as short-term drops in renewable production need to be rapidly compensated by backup conventional fossil fuel generation, battery storage or other measures. As renewable energy production is distributed across a region, the risk of 'intensity drops' in renewable output can be lessened as, for example, not all installations will be affected by changes in cloud or wind at the same point in time. This means that a good understanding of the variability in these natural resources by location and time is essential, and this is not always supported by current sources of data.

A lack of confidence in the current data observations can lead to over-conservative assumptions about the requirements for back-up (leading to increased operational costs), or increased perception of risk from investors (leading to increased costs of lending).

## 2.2. The RE-SAT solution

The RE-SAT project has addressed these challenges by **developing an energy analytics platform** to support the transition to renewable energy and by **using weather observations, satellite data products and modelling techniques** to enhance and fill in gaps in the weather data record. The

[2] The Montserrat Energy Policy 2016 – 2030. Prepared by Ministry of Communications, Works, Energy & Labour (2016). https://www.gov.ms/wp-content/uploads/2020/07/The-Power-to-Change-MNEP-Cabinet-Approved.pdf

software platform allows users to access these enhanced datasets and use them to provide improved renewable energy resource estimates for investing and planning purposes.

RE-SAT Phase 1 (December 2016 – November 2017) focused on Seychelles and the IEA engaged with a team of end users drawn from the main energy-related government agencies within Seychelles. Through a series of workshops and training sessions the IEA refined the functional requirements for RE-SAT under three categories of development:

1. Data and modelling.
2. Platform capabilities and features.
3. Capacity building.

RE-SAT Phase 2 built on what was learned and developed in Phase 1 to apply the platform to a range of other SIDS including Montserrat, in order to prove its usefulness and commercial viability in different countries with separate renewable energy demands. The ability to expand the concept's geographical scope is a key strength of an Earth Observation based solution.

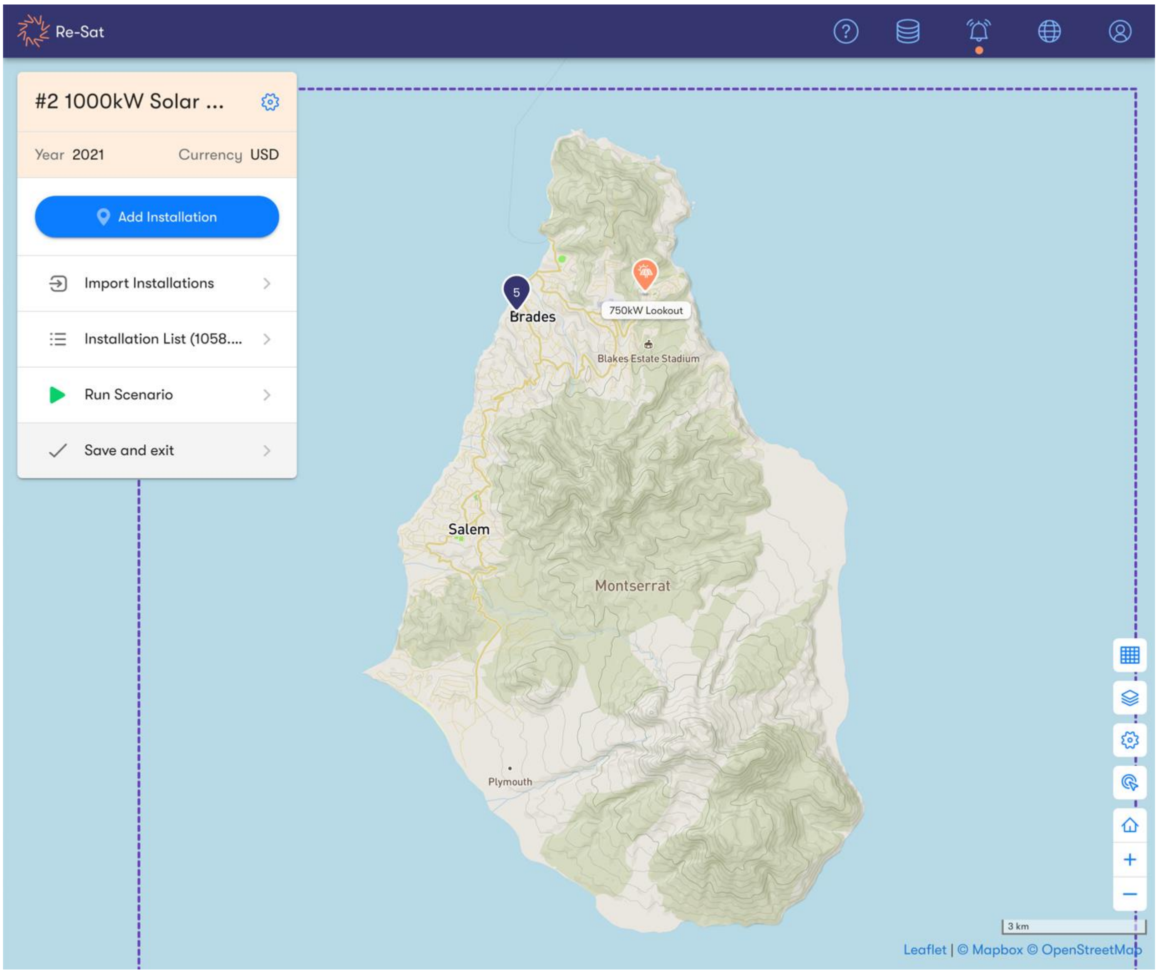



*Figure 5: Example scenario for the RE-SAT application (re-sat.com). The user can create renewable energy scenarios and explore the results of those already run.*

## 2.3. Targeting the UN Sustainable Development Goals

RE-SAT supports the transition towards low carbon energy in SIDS and contributes towards two key aspects: energy reliance and climate change mitigation.

- **Sustainable Goal 7 – Affordable and Clean Energy** - SIDS are heavily dependent on expensive, vulnerable, petroleum-based power generation (~85% across all the SIDS (IRENA[3], 2014) and spend 15-20% of disposable income on electricity (versus 5-10% in the OECD). Paradoxically, SIDS have abundant RE resources ranging from solar and wind to geothermal and hydro. However, the cumulative RE adoption across SIDS is less than 15% of total capacity (IRENA, 2014).

- **Sustainable Goal 13 - Climate Action** – Despite emitting less than 1% of global greenhouse gases, SIDS are very vulnerable to the effects of climate change including rising sea levels, seawater infiltration, land erosion and severe storms.

Increasing the use of renewable energy on island states will improve energy security and tackle climate change, leading ultimately to a more sustainable economic growth in the SIDS.

Our programme aligns primary to SDG 7 and the specific target 7.2: “By 2030, increase substantially the share of renewable energy in the global energy mix”, with its indicator: 7.2.1 “Renewable energy share in the total final energy consumption”.

In addition, part of our work also contributes to SDG 10 Reduced Inequalities (e.g., through better targeting renewable energy projects at low-income groups) and SDG 11 (Sustainable Cities and Communities).

[3] IRENA: International Renewable Energy Agency

# 3. Project partners

Our lead partner in Montserrat is the Energy unit within the Ministry of Communications, Works, Energy and Labour (MCWEL). Other government departments and agencies involved in the project included the Montserrat Utilities Limited (MUL), the Statistics Department, The Physical Planning unit at the Ministry of Agriculture, Trades, Lands, Housing, and the Environment (MATLHE) and the Department of Information, Technology and eGov Services (DITES).

The role of the government has been to facilitate access to the findings regarding the actions from the Energy Policy Plans towards renewable energy by providing expert knowledge into the particular RE requirements and potential sources of data. They have provided valuable power data for our validation purposes. The GIS unit have been instrumental in the provision of GIS layers that are available in the platform. These are a visual aid when siting new installations.

***Figure 6**: Montserrat project partners at RE-SAT workshop with part of the IEA team (May 2019).*

# 4. Developing the RE-SAT platform

## 4.1. Understanding user needs - common high-level functionalities

After initial assessments with all stakeholders in each island, the value chain displayed in the figure below was captured to show how RE-SAT capabilities were intended to benefit the SIDS stakeholders

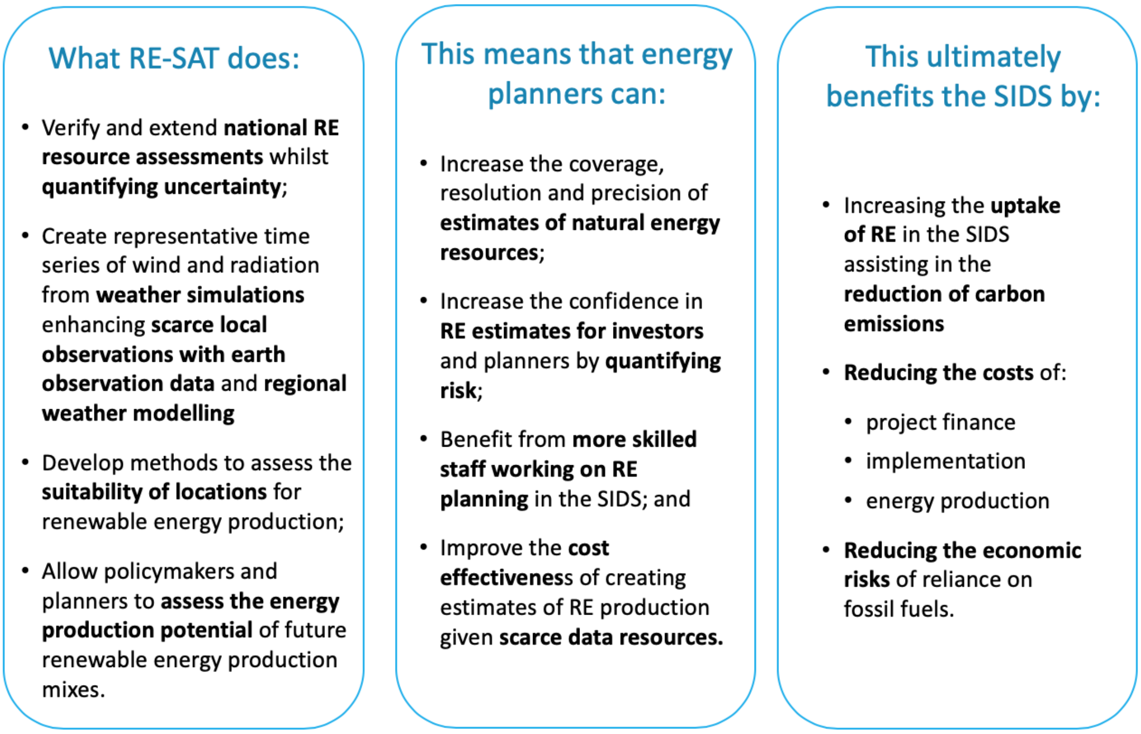



*Figure 7: RE-SAT intended value chain.*

The following high level functional requirements were identified, common to all partner SIDS.

| High level Requirement |
|---|
| Resource maps - Identify the likely aggregate variation in weather variables affecting energy production (insolation, wind speed, wave height) by location and represent in the form of a map. |
| Weather data - Quantify the expected variation in weather variables affecting energy production by location over a simulated time period.<br>The simulated weather variables will:<br>• Range over multiple years (sufficient to capture modes of multi annual variation e.g., ENSO).<br>• Reproduce as far as possible the climatology for each nominated location.<br>• Preserve realistic meteorological inter-area correlations.<br>• Provide simulated data points at nominated time resolutions with no missing gaps, at a nominated spatial resolution. |

<table>
<tr><th>High level Requirement</th></tr>
<tr><td>Location assessment - Identify potential feasible and optimal locations for the placement of RE installations considering multiple decision criteria and constraints (environmental, regulatory and legal). Functionality is needed to:
<ul>
<li>Facilitate the overlay of GIS layers for location identification. These layers are likely to include: resource maps, terrain models, land use, transport networks, electric grid infrastructure, optical imagery, building outlines, flooding, landslide, storm hazards, existing RE installations.</li>
</ul></td></tr>
<tr><td>Power output estimation<br>Create future scenarios for power output from new RE installations, required for:
<ul>
<li>Strategic planning.</li>
<li>Response to national communications to the UNFCCC.</li>
<li>Procurement exercises for RE or grid infrastructure.</li>
<li>Support proposals for new infrastructure.</li>
</ul>
Users need to be able to:
<ul>
<li>Load pre-selected site locations for installations.</li>
<li>Load existing installation specifications into a scenario.</li>
<li>Locate installations ‘by hand’ on a map.</li>
<li>Define the technical specification of wind and solar installations, sufficient to allow estimates of power production from simulated realistic weather conditions.</li>
<li>Define financial attributes for each scenario and installation, sufficient to estimate a “first order” levelised cost of energy (LCOE) over the installation lifetime (e.g., attributes such as capital expenditure, operation expenditure, inflation, financial discount rates, installation lifetime).</li>
<li>Compare the output of a group of installations with a user specified range of demand scenarios, in order to estimate how much renewable production will fall short of or exceed demand throughout each day in simulated weather years.</li>
<li>Simulate the energy production from a specified mix of RE installations against a range of realistic weather conditions. Estimate the total amount of power that would be generated, and its variability over a nominated time resolution.</li>
<li>Quantify the uncertainty of given levels of energy generation for installations in a scenario, known as exceedance probabilities P10, P50 and P90.</li>
<li>View the results of the simulation by individual installation and at varying time resolutions (hourly, day, week, month, year). Guide the user to significant conditions in the weather simulations (for example periods of maximum or minimum generation or rate of change of power production).</li>
<li>Allow variations on scenarios at different points in time to be easily developed, compared and evaluated, accounting for installation aging and changes in demand.</li>
<li>Allow users to collaborate by sharing and developing scenarios within and between stakeholder teams.</li>
</ul></td></tr>
<tr><td>Training and knowledge sharing
<ul>
<li>Deliver training to nominated users on how to use the data products and software platform.</li>
<li>Provide a way to exchange knowledge within the country and across countries regarding the use of RE-SAT and renewable energy related issues.</li>
</ul></td></tr>
<tr><td>Access to RE-SAT
<ul>
<li>Provide secure access to the platform, through unique logins to key stakeholders.</li>
</ul></td></tr>
</table>

## 4.2. Specific requirements in Montserrat

The following specific requirements were requested by stakeholders in Montserrat.

Resource maps – to support location assessment of the future solar and wind RE installations:
- Solar map
- Wind map
- Wave map

Weather data:
- Global resolution data for a national assessment of potential solar and wind generation.
- High resolution solar and wind data to support the investment case for grid connected project, required for a more detailed assessment of regional potential and to inform evidence-based decisions and support financial investment. For Montserrat, the resolution of the weather data developed was of 330m, due to the small size of the country.

Building layer.
- The Montserrat GIS team enquired whether optical satellite imagery could be used to help create a digitised GIS layer for building outlines as this is required for a number of purposes, including planning for rooftop PV installations.

Cost assessment
- Add economic cost analyses calculations for different renewable installation types within RE-SAT.

Geothermal
- Include contributions from geothermal resources when developing renewable energy scenarios. This was requested as initial geothermal test sites have been drilled in Montserrat, although these are not in production they may represent a source of renewable production for Montserrat in the future.

Capacity building
- Training package to help users navigate through the software platform.

Meeting these requirements through developing new functionalities in RE-SAT meant that that those responsible for RE planning in the Montserrat would be able to:
- Increase the coverage, resolution and precision of estimates of natural resources needed.
- Increase the confidence in RE estimates for investors and planners.
- Benefit from more knowledgeable and skilled staff working on RE planning.
- Improve the efficiency and effectiveness of creating estimates of RE production.

Over time these will contribute towards improved decision-making, reduced costs of implementation and increased uptake of renewable energy in Montserrat, helping to reduce the cost of energy production and reducing the economic risks of reliance on fossil fuels.

## 4.3. Responding to requirements – the technical solution

Through a collaborative process, the IEA team tailored the project to the needs of the Government of Montserrat and developed a set of agreed targeted objectives with short-term benefits for Montserrat as well as long-term benefits.

The RE-SAT functional requirements, as developed in consultation with Montserrat partners, were separated into three categories:

a) Data and modelling
b) Platform capabilities and features
c) Capacity building

### 4.3.1. Data and modelling

1. Weather data: Analysed and simulated weather data for coupled wind and solar resources. These weather datasets were created based on a bespoke local area high-resolution (330m x 330m) numerical weather model configured by the IEA for Montserrat. They include wind speed, incoming shortwave radiation, temperature, and Global Horizontal Irradiance (GHI). A wave dataset was also generated directly from the 30kmx30km Reanalysis data (ERA5) used to drive our high-resolution weather model.

   Satellite data is being used to enhance our estimates of GHI. Surface radiation products from: OSI-SAF (Meteosat and GOES-East) and JAXA (Himawari 8) are used as RE-SAT's primary source of data for the estimation of solar power production. Satellite derived estimates of the incoming flux of shortwave radiation are generally preferred over the estimates from our weather model simulations due to the difficulty of accurately simulating cloud cover. The situation is reversed towards local dawn and dusk when the remotely sensed estimates become unreliable, at which point we fall back to the weather model data.

2. Resource maps: A guide to the abundance of energy available for a particular type of renewable generation by location. Resource maps were developed for: solar, wind and wave (see Figure 8).

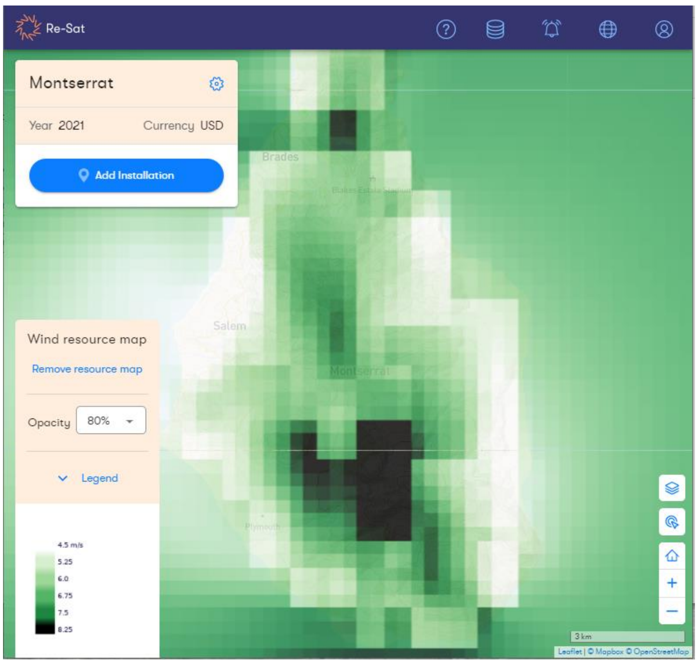



*Figure 8: Wind resource map for Montserrat.*

3. <u>GIS map layers</u>: These are layers, either provided by the partner country or created by the IEA, including buildings, conservation zones, energy grid, etc. For Montserrat, the following GIS layers are available: buildings, roads and the volcanic exclusion zone.

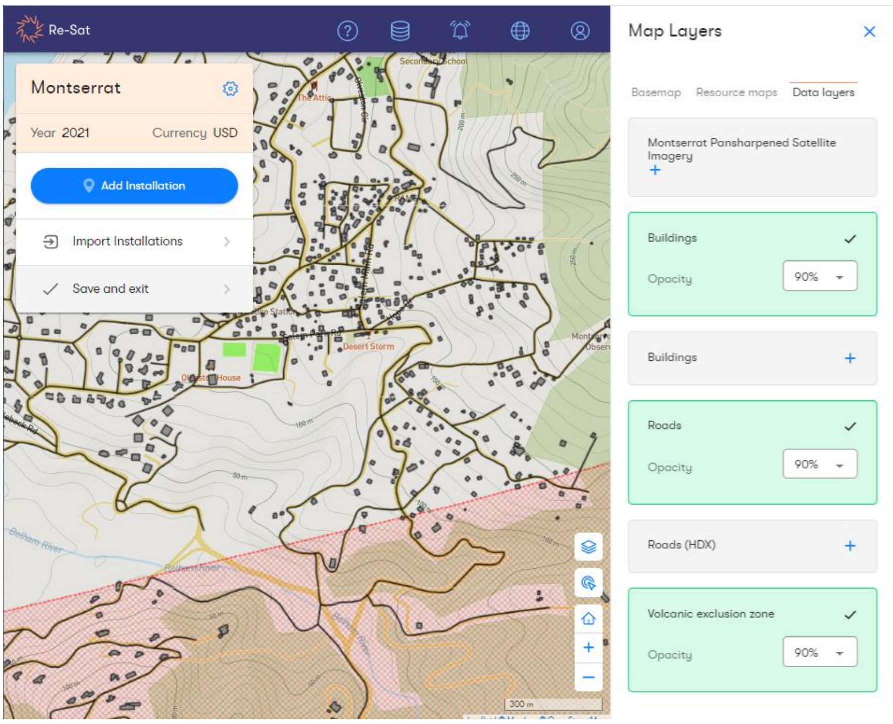



*Figure 9: Example of some of the GIS layers available in the RE-SAT platform for Montserrat.*

### 4.3.2. Platform capabilities and features

1. <u>Location assessment</u>: A capability to use the resource maps together with a combination of GIS layers to assess suitable locations for new renewable energy installations.

2. <u>Renewable scenario settings and installations characteristics</u>: The capability to create future configurations of mixed renewable energy installations. RE-SAT offers templates of generic installation types and those that have been already used or specified by the user, adding to the bespoke nature of the application.

3. <u>Variable Renewable Energy simulation (VRE simulation)</u>: RE-SAT models the energy generated and its variability from a combination of VRE installations as specified by the user. The results are based on the multi-year weather data developed and tailored for Montserrat.

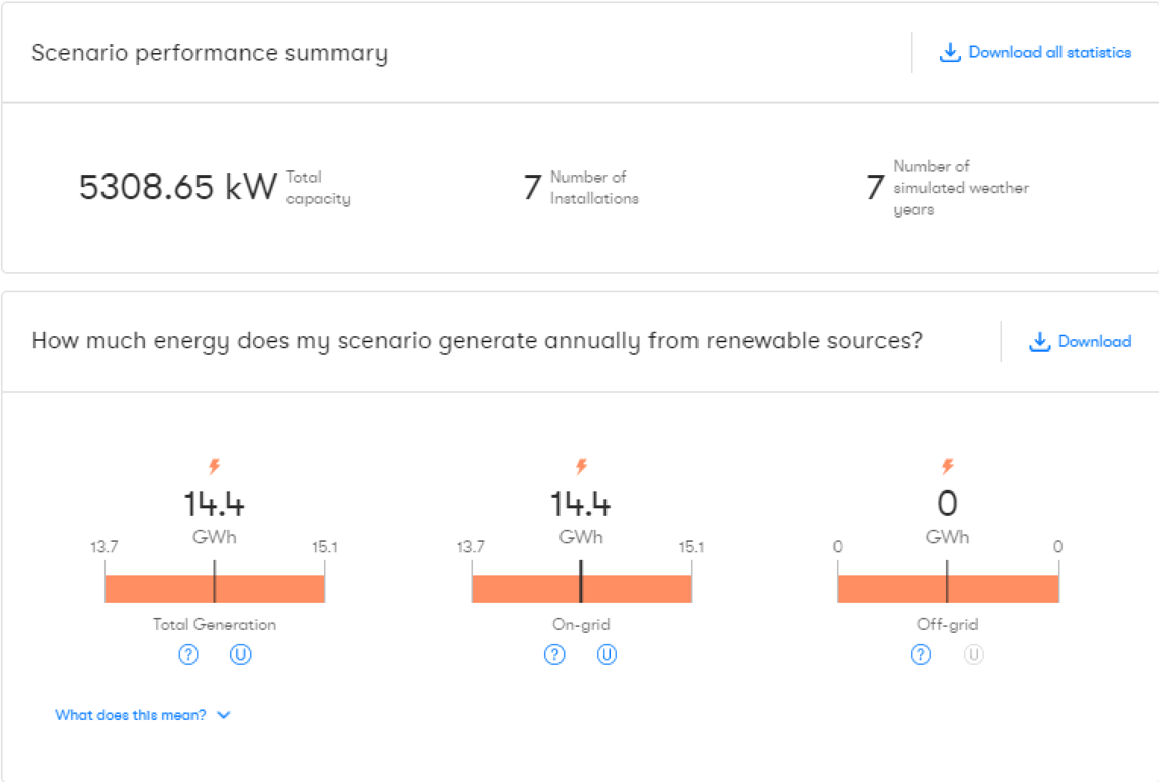



*Figure 10*: *Example of the scenario performance summary display in RE-SAT.*

4. Geothermal, hydro and biofuel contributions: Capability to add power estimated from these installation types. These are added by the user as fixed outputs or predetermined time-series of production.

5. CO2 and fossil fuel displacement: RE-SAT calculates the potential for displacement of fossil-fuel related costs and CO2 emissions saved from the modelled renewable energy scenario.

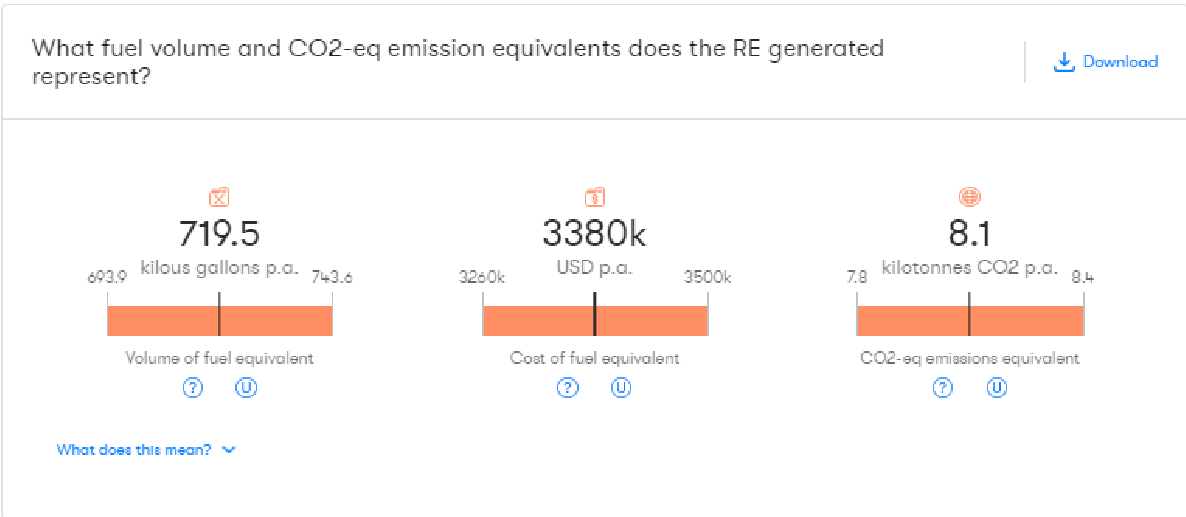



*Figure 11*: *Example of the results of the CO2 and fossil fuel displacement calculations in RE-SAT.*

6. Uncertainty quantification: RE-SAT reports generation estimates at different exceedance probabilities, expressing how often it is likely that a given annual quantity will be exceeded when measured repeatedly over several years (to account for year-on-year variability). Confidence interval on each of these estimates are also provided (to account for modelling uncertainty).

7. Demand comparison: If a yearly load curve (demand for electricity) is provided for the scenario, RE-SAT compares the RE generated by the scenario versus the demand, e.g., the platform quantifies what residual load remains after considering the renewable contribution. This gives an indication of the amount of energy that still need to be generated by other sources to meet that demand.

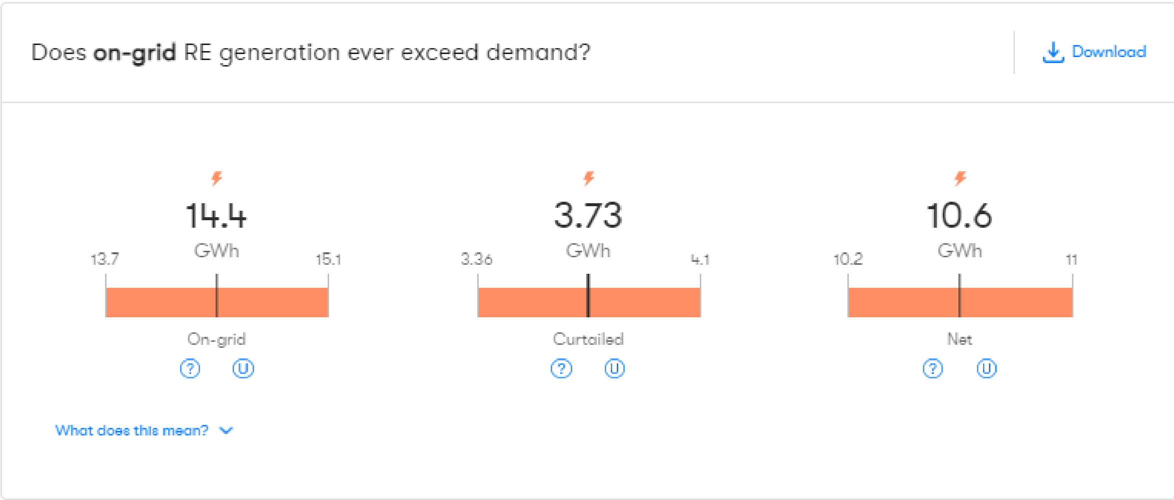



***Figure 12**: Example of summary results for the demand comparison analysis in RE-SAT.*

8. Financial analysis: Capability to assess the relative cost of one scenario or technology type versus another. RE-SAT performs a levelised cost of renewable energy calculation. All the financial assumptions regarding costs of installations, inflation, etc. were tailored for Montserrat and arrived at in consultation with partners.

   Figure 13 shows an extract from a discounted cash flow model automatically created from a scenario in the RE-SAT application. The model can be downloaded by the user in the form of an EXCEL spreadsheet and shows all assumptions made and the basis of the calculation. This allows the user to perform sensitivity analysis on all input assumptions when calculating a levelised cost of energy (known in RE-SAT as a levelised cost of renewable generation or LCORG) for the energy generated from a specific installation to account for uncertain knowledge. The levelised cost of energy is a common industry metric used to estimate and compare energy costs. The use of satellite data reduces the uncertainty in production estimates and therefore cost estimates.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **LEVELISED COST OF RENEWABLE GENERATION CALCULATION** | | | | | | | | |
| **Scenario name** | #2 1000kW Solar Scenario 2021 | | | | | | | |
| **Installation name** | 750kW Lookout | | | | | | | |
| **Exceedence probability** | 50.00% | | | | | | | |
| **Bound** | middle | | | | | | | |
| **Installation year** | 2021 | | | | | | | |
| **Installation AC capacity** | 652.00 kW | | | | | | | |
| **Year** | y | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| **REPLACEMENT** | | | | | | | | |
| **Generator residual due** | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Inverter age** | years | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| **Inverter residual due** | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Inverter replacement due** | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Inverter value after depreciation** | USD_2021 | 250,074.60 | 222,288.53 | 194,502.47 | 166,716.40 | 138,930.33 | 111,144.27 | 83,358.20 |
| **Degradation Factor** | - | 1.00 | 1.00 | 0.99 | 0.99 | 0.98 | 0.98 | 0.97 |
| **Degraded Annual Energy** | kWh | | 1,139,620.72 | 1,133,922.62 | 1,128,253.00 | 1,122,611.74 | 1,116,998.68 | 1,111,413.69 |
| **NOMINAL CASHFLOW** | | | | | | | | |
| **Nominal Discount Factor** | - | 1.00 | 0.93 | 0.87 | 0.81 | 0.75 | 0.70 | 0.66 |
| **Nominal Inflation Factor** | - | 1.00 | 1.02 | 1.04 | 1.06 | 1.08 | 1.10 | 1.13 |
| **Nominal Discounted Degraded Energy** | kWh | | 1,062,088.28 | 984,881.49 | 913,287.12 | 846,897.19 | 785,333.37 | 728,244.83 |
| **Nominal Cumulative Energy** | kWh | | 1,062,088.28 | 2,046,969.76 | 2,960,256.88 | 3,807,154.07 | 4,592,487.44 | 5,320,732.26 |
| **Nominal generator residual inflated** | USD_2021 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Nominal inverter residual** | USD_2021 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Nominal inverter replacement** | USD_2021 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Nominal inverter value on generator en** | USD_2021 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Nominal Opex** | USD_2021 | | -11,735.10 | -11,969.80 | -12,209.20 | -12,453.38 | -12,702.45 | -12,956.50 |
| **Nominal Opex of production** | USD_2021 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Nominal Total Cashflow** | USD_2021 | -1,400,724.60 | -11,735.10 | -11,969.80 | -12,209.20 | -12,453.38 | -12,702.45 | -12,956.50 |
| **Nominal Discounted Cashflow** | USD_2021 | -1,400,724.60 | -10,936.72 | -10,396.51 | -9,882.98 | -9,394.82 | -8,930.77 | -8,489.64 |
| **Nominal Cumulative Discounted Cashflc** | USD_2021 | -1,400,724.60 | -1,411,661.32 | -1,422,057.83 | -1,431,940.81 | -1,441,335.63 | -1,450,266.40 | -1,458,756.04 |
| **Nominal Total Cost** | USD_2021 | -1,400,724.60 | -11,735.10 | -11,969.80 | -12,209.20 | -12,453.38 | -12,702.45 | -12,956.50 |
| **Nominal Discounted Cost** | USD_2021 | -1,400,724.60 | -10,936.72 | -10,396.51 | -9,882.98 | -9,394.82 | -8,930.77 | -8,489.64 |
| **Nominal Cumulative Discounted Cost** | USD_2021 | -1,400,724.60 | -1,411,661.32 | -1,422,057.83 | -1,431,940.81 | -1,441,335.63 | -1,450,266.40 | -1,458,756.04 |
| **REAL CASHFLOW** | | | | | | | | |
| **Real Discount Factor** | - | 1.00 | 0.95 | 0.90 | 0.86 | 0.82 | 0.78 | 0.74 |
| **Real Inflation Factor** | - | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **Real Discounted Degraded Energy** | - | | 1,083,330.04 | 1,024,670.70 | 969,187.60 | 916,708.75 | 867,071.49 | 820,121.96 |
| **Real Cumulative Energy** | - | | 1,083,330.04 | 2,108,000.74 | 3,077,188.34 | 3,993,897.09 | 4,860,968.58 | 5,681,090.54 |
| **Real generator residual inflated** | USD_2021 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Real inverter residual** | USD_2021 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Real inverter replacement** | USD_2021 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Real inverter value on generator end of** | USD_2021 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Real Opex** | USD_2021 | | -11,505.00 | -11,505.00 | -11,505.00 | -11,505.00 | -11,505.00 | -11,505.00 |
| **Real Opex of production** | USD_2021 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Real Total Cashflow** | USD_2021 | -1,400,724.60 | -11,505.00 | -11,505.00 | -11,505.00 | -11,505.00 | -11,505.00 | -11,505.00 |
| **Real Discounted Cashflow** | USD_2021 | -1,400,724.60 | -10,936.72 | -10,396.51 | -9,882.98 | -9,394.82 | -8,930.77 | -8,489.64 |
| **Real Cumulative Discounted Cashflow** | USD_2021 | -1,400,724.60 | -1,411,661.32 | -1,422,057.83 | -1,431,940.81 | -1,441,335.63 | -1,450,266.40 | -1,458,756.04 |
| **Real Total Cost** | USD_2021 | -1,400,724.60 | -11,505.00 | -11,505.00 | -11,505.00 | -11,505.00 | -11,505.00 | -11,505.00 |
| **Real Discounted Cost** | USD_2021 | -1,400,724.60 | -10,936.72 | -10,396.51 | -9,882.98 | -9,394.82 | -8,930.77 | -8,489.64 |
| **Real Cumulative Discounted Cost** | USD_2021 | -1,400,724.60 | -1,411,661.32 | -1,422,057.83 | -1,431,940.81 | -1,441,335.63 | -1,450,266.40 | -1,458,756.04 |
| **FINANCIAL MEASURES** | | | | | | | | |
| **Lifetime measures** | | | | | | | | |
| **LCC** | USD_2021 | 1,784,249.61 | | | | | | |

*Figure 13: Extract from a discounted cash flow model automatically created from a scenario in the RE-SAT application.*

9. Results exploration: RE-SAT presents results via interactive visualisations that show generation by year, month, day, hour or even at the 10-minute level. Charts can be customised for the different sources allowing the user to look at the expected intermittency and what good and bad production looks like. Generation profiles can be overlaid with demand curves, residual load curves and potential curtailment.


***Figure 14**: Examples of results exploration capabilities in RE-SAT (Generation Heatmap and Demand Heatmap).*


*Figure 15: Examples of results exploration capabilities in RE-SAT.*

10. Data repository: All dataset developed (weather data, GIS layers and resource maps) and results from scenarios are stored under a data repository, for easy access and download.

11. Technical Manual: An online Help Manual with step-by-step explanations of how to use RE-SAT together with technical explanations is also available from the platform.

> *"Whatever suggestions or recommendations that we made, there was an attempt to actually incorporate those recommendations. That was very good. If we said that this was an issue or this is something that can potentially be used, there was a willingness to incorporate it, and I must commend you guys for that. There was an effort to always try to meet the needs of the clientele which was very valuable."* **Kenrick Burke, Director of Energy (MCWEL)**

### 4.3.3. Capacity building

One of the key aspects of the project is the exchange of knowledge and expertise with our partners regarding the use of earth observation data, environmental modelling, data analysis and renewable energy. This has been realised through the Working Group meetings and a series of visits and interactive workshops. A total of 8 users in Montserrat have access to the platform.

> *"This project has helped to introduce me to simulating these [scenarios]. I have never used a simulation platform before in this way, so that was very helpful for me in building my capacity as energy officer, to be further helpful to my team in these kind of scenarios in terms of looking at projects and evaluating projects."* **Oswen Carty, Energy Officer (MCWEL)**

## 4.4. Delivering value and benefits – innovations

The main two areas where RE-SAT is pushing the boundaries within renewable energy planning are:

- **Strategic support for national energy planning:** The intuitive interface and workflow allows rapid modelling of different renewable generation scenarios. Scenarios provide a convenient way to explore options for achieving a range of renewable energy-related objectives:
    - <u>Nationally Determined Contributions</u> - Quantifying the extent to which renewable energy projects can contribute towards more ambitious Nationally Determined Contributions.
    - <u>Integrated Resource Plans</u> - Developing strategies for ensuring future supplies of electricity as part of integrated resource (and resilience) planning.
    - <u>National Energy Transition Strategies</u> - To inform planning, policy and procurement strategies for increasing the penetration of renewable energy as part of generation expansion aspirations and overarching energy transition.

- **Project pre-feasibility evaluation:** The software is designed to make it quick and easy to complete a pre-feasibility renewable energy analysis.
    - <u>Site selection</u> - Our high-resolution resource maps combined with integration of geospatial data (GIS layers) inform strategic site selection of new installations - providing a pre-feasibility check without the need for lengthy site surveys.
    - <u>Generation profiles</u> - The platform analytics provide detailed characterisations of renewable energy generation profiles and generation versus demand, which provides information about the utilities company power needs - leading to potential government savings on unnecessary infrastructure costs.
    - <u>Portfolio effects</u> - The ability to model single installations or complex combinations of different plants in different locations supports the exploration of potential portfolio effects.

- o <u>Investment cases</u> - The platform provides a comprehensive suite of energy metrics that can support the development of robust investment cases and more bankable project proposals.
- o <u>Proposal assessment</u> – RE-SAT provides an independent and standardised method or assessing renewable energy proposals received.

**The RE-SAT weather datasets are the engine behind the platform and what drive the calculations of our energy metrics**. The performance of installations exploiting variable renewable energy sources, like solar and wind, relies on weather. RE-SAT calculations are driven by our high-resolution weather datasets. These are multi-year simulations of key weather variables that we create using a regional high-resolution weather model combined with satellite data and any available local weather observations. The result is a high spatial (1km) and temporal resolution (10-minute timestep) weather dataset which is tailored to a particular geography.

**The project has also delivered the following benefits regarding capacity building**

- Training in EO, weather modelling and RE concepts leading to partners being better equipped to plan their future renewable energy infrastructure needs.
- More knowledgeable and skilled staff working on renewable energy planning – delivering technical support and training to deploy and utilize RE-SAT for in-country decision-making.
- A knowledge-sharing platform to foster a wider exchange of experiences in the use of the data and the platform for in-country users.

## 4.5. Validation exercise - how does RE-SAT performs in Montserrat?

The RE-SAT platform was used to simulate the power produced by the existing solar arrays installed at Brades (250kW of generation capacity).

The output from RE-SAT was compared with the actual power produced by the installations from October to December 2019. The power data was kindly provided by the Government of Montserrat.


*Figure 16: Placard for the 250kW solar PV project in Montserrat.*

The comparison considered two key elements:

1. The accuracy of the simulations.
2. The calibration of the uncertainty estimates.

### 4.5.1. Accuracy

This was assessed using the Bias and the Mean Absolute Error (MAE). These quantities measure how far RE-SAT's power estimates are from the truth. Figure 17 below compares the simulated power from RE-SAT (red line) with the observed production (black dots).

The bias is defined as the mean distance of the black dots from the red line. If the simulated values are consistently higher than reality (red line typically above the dots) the bias is positive. Similarly, a negative bias would mean that the dots typically lie above the line and the simulation would be systematically under predicting the power.

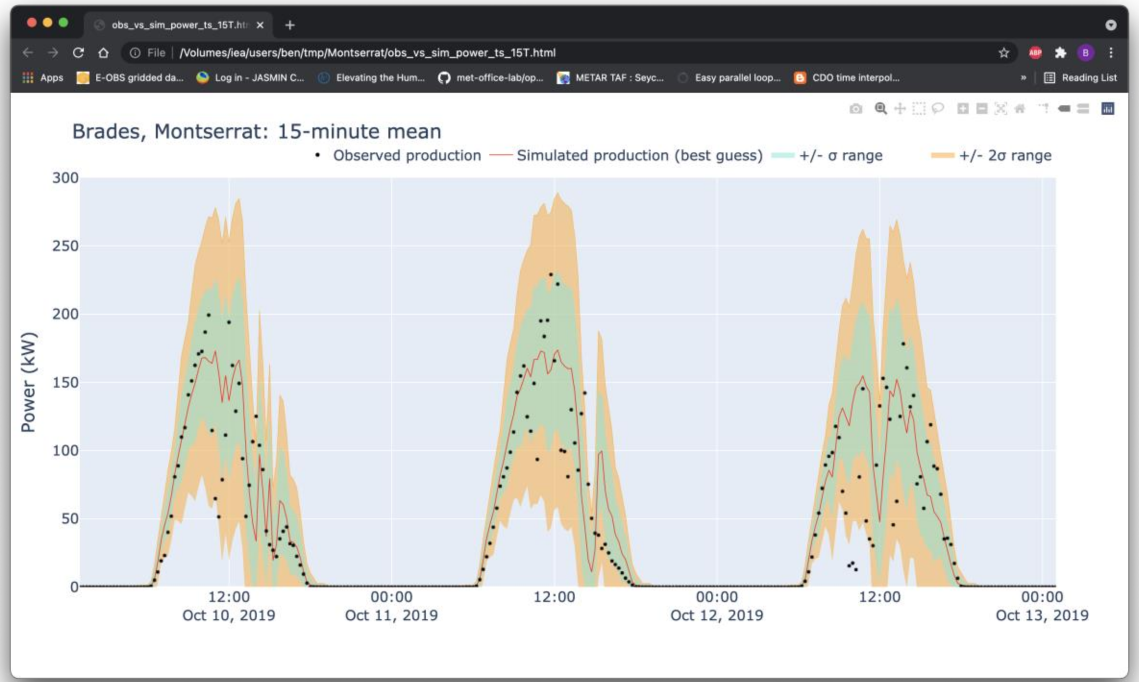



*Figure 17: RE-SAT performance compared with observed production for the 250kW solar installations in Brades. The black dots represent the overserved power produced, the red line is the simulated production by RE-SAT, the colour bands are a representation of the uncertainty (1 sigma or 2 sigma).*

Low bias is a necessary condition for a 'good' simulation, but it is not sufficient. A good simulation will have low bias with all points scattered close to the red line (the production simulated by RE-SAT). A poor simulation may also have low bias but with points scattered widely about the line (equal numbers of under and over predictions compensate on average). The mean absolute error is used to distinguish between the two cases.

In summary, a good simulation will have both low bias (the simulation is accurate) and low MAE (the simulation has high precision).

The comparison shown in Figure 17 is for power measured in (kW). This is useful for a particular generator, but it is difficult to compare bias and MAE between generators of different sizes. Thus, it is normal to report errors, and likewise bias and MAE, expressed as a percentage of the installed capacity. Figure 18 summarises the simulation errors for the Brades site as measured on the 15-minute average power (upper panel) and the average daily power (lower panel). Since solar simulation errors are trivially zero at night-time only values for daytime are included in the analysis.

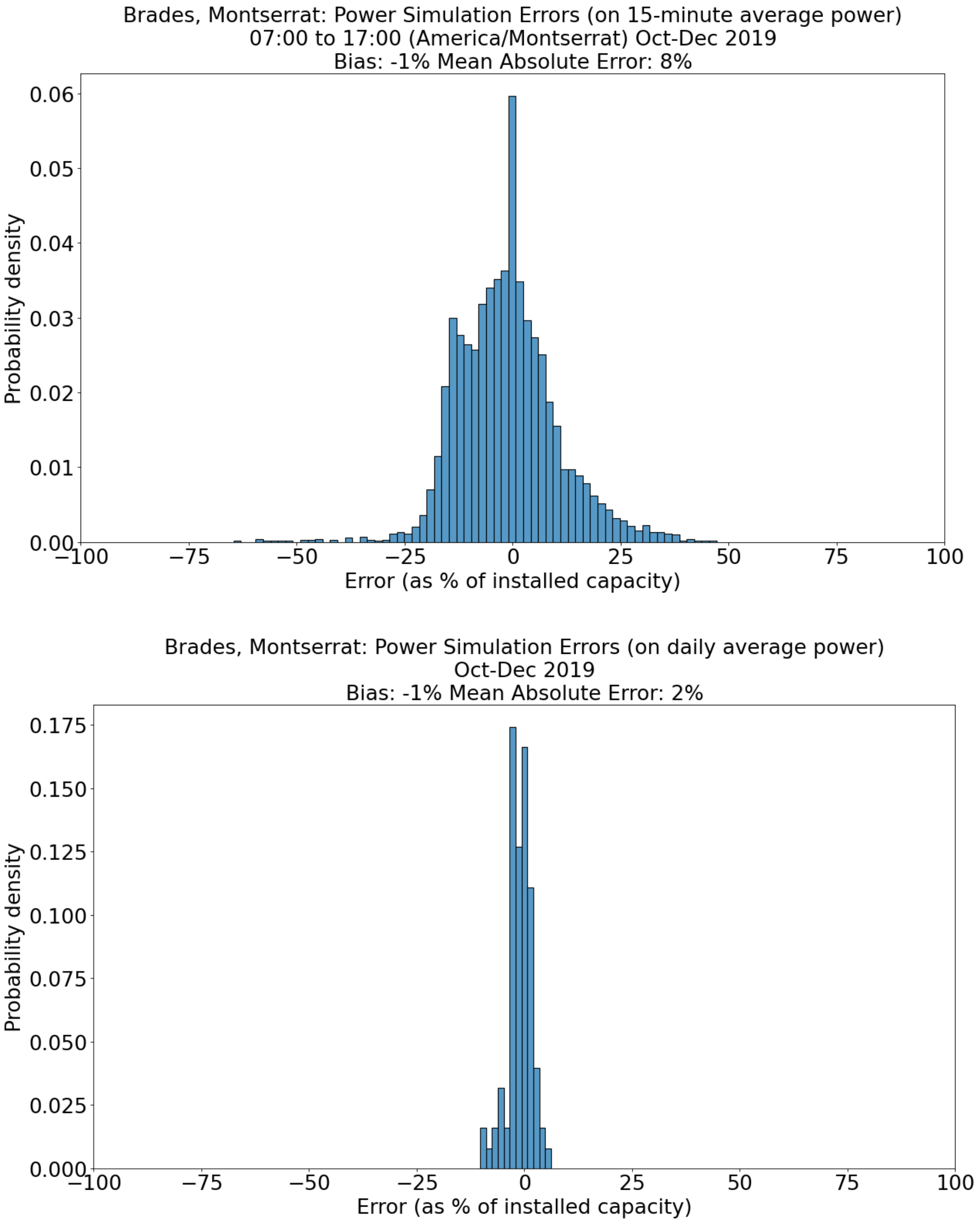



***Figure 18**: Histogram of RE-SAT simulation errors for the 250kW solar installations in Brades as measured on the 15-minute average power (upper panel) and the average daily power (lower panel).*

### 4.5.2. Uncertainty calibration

The orange and green bands shown in Figure 17 represent the uncertainty bands which are reported for each simulated quantity estimated by RE-SAT. The uncertainty bands are reported in terms of the expected standard deviation of the power estimate in the hypothetical situation that the comparison could be repeated many times. If we treat each power estimate in the time series of the simulation as likely as any other, then under the assumption that the errors (the difference between simulation and reality at each time) are normally distributed then we expect to find a fixed proportion of the observations (the black dots in Figure 17) to fall outside of the uncertainty bands.

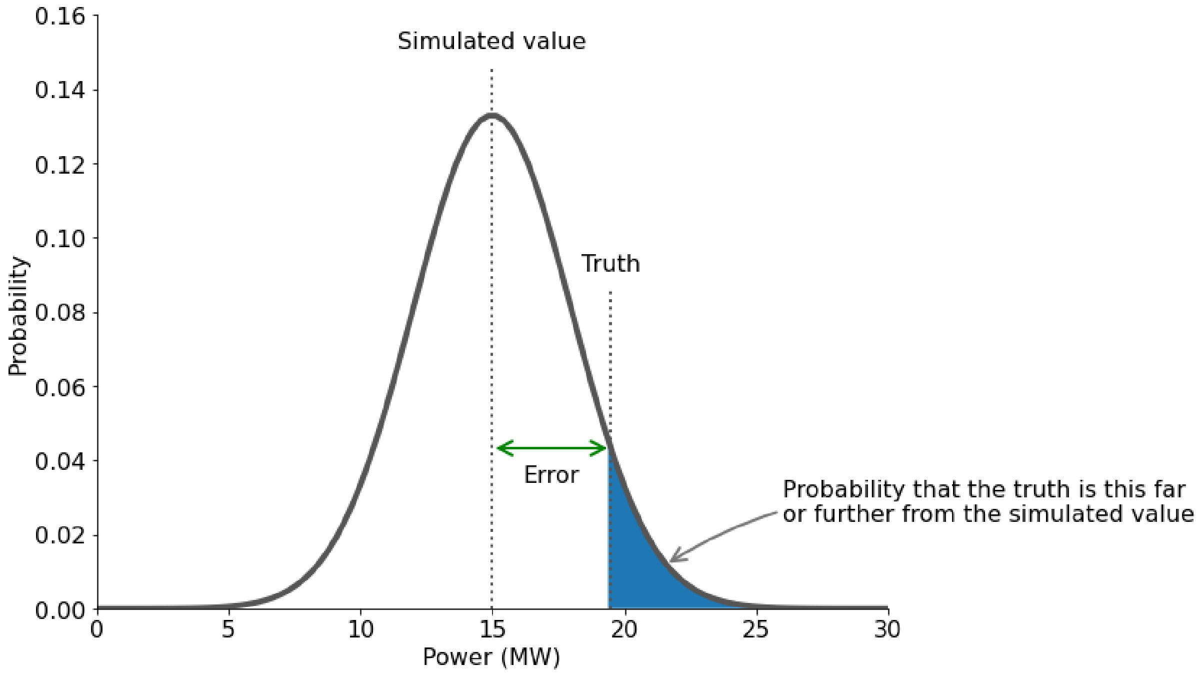



***Figure 19**: Normal distribution of the simulation errors.*

Under the assumption that the simulation errors follow a normal distribution (as shown in Figure 19) then the probability of a particular observation of the power falling outside of the top of the one-sigma band is 13.6% and there is a similar 13.6% chance that the observation falls below the band. Thus, if the uncertainty bands are well calibrated, we expect around 75% (100% – 2 x 13.6% ≈ 75%) of the observations to reside within the one-sigma band. Similarly, we expect approximately 95% of all observations to reside in the two-sigma band. This is illustrated in Figure 20.

The distribution of the simulation errors is shown in the histograms of Figure 18. Whilst not perfectly normal, the distributions are close enough to normal to warrant a reasonable judgement to be made of the width of the sigma bands reported by RE-SAT. To this end, the proportion of excursions (black dots outside of the bands in Figure 17) were computed. Reality was inside of the one-sigma approximately 95% of the time. Reality was inside of the two-sigma approximately 99% of the time. These numbers are smaller than the 75% and 95% expected and indicate that the uncertainty bands reported by RE-SAT are too wide.

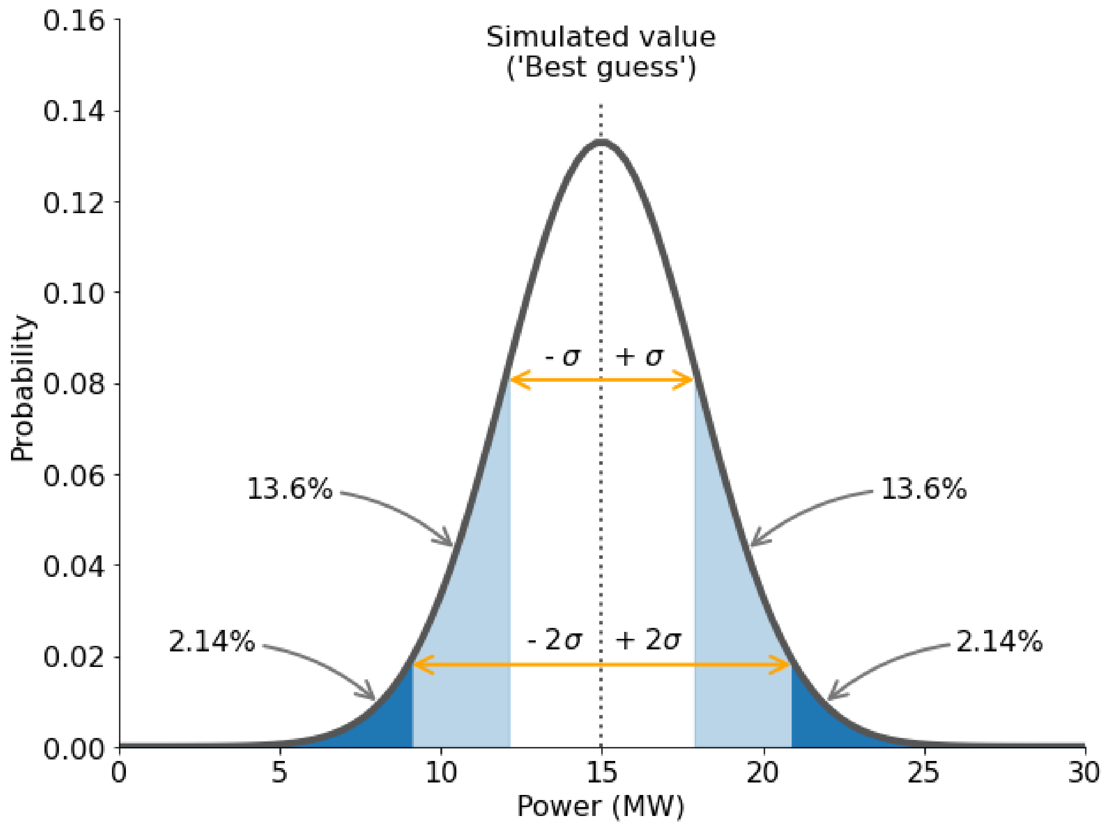



*Figure 20: Probabilistic interpretation of sigma-bands under the assumptions of normally distributed errors.*

In summary:

- Results typically within: 8% for any given 15-minute average, 2 % for any given daily average.
- Tendency to under predict production by about 1%.
- Uncertainty bands are too wide. We could narrow them by calibrating against local production data, but we would need to simulate additional weather data for 2020.
- Errors should improve when we blend GOES-East weather satellite observations into the simulated weather data.

## 4.6. Launch of RE-SAT in Montserrat

The RE-SAT platform was launched in Montserrat during a virtual two-day Training Workshop (29-30 June 2021), where the IEA team trained participants on the use of RE-SAT and developed some real energy scenarios with them.

> *"We were able to input data and calculate our carbon footprint based on the RE-SAT platform. That is something that a lot of agencies and stakeholders across the region have been asking for, and many persons and many countries are not able to give that to them, so I am happy that we should be able to provide that sort of information to our stakeholders in the region in the near future using the RE-SAT platform."* **Jasmine Jno-Baptiste, Social Statistician (Statistics Department)**

# 5. Sustainability model

RE-SAT has successfully reached market readiness, though still with much potential to evolve. Efforts are now focused on transitioning from the funded project phases to the unfunded commercial phase. Sustainability requires users to pay a subscription fee to use the platform.

The sustainability model focuses on making RE-SAT available to users via a commercial licensing model based on the development of the platform and data products for each new region/country. The funded phases have allowed for the co-design of the platform functionality in collaboration with 7 countries, for which relevant weather data and customised platform for their needs have been prepared.

A commercial model has been developed to support the transition to the unfunded commercial phase, which includes:

- a bottom-up cost model.
- a pricing model (including mechanisms to scale certain parts of the cost base in response to changing customer requirements), and
- a service agreement defining the terms under which the application will be licensed.

Revenue modelling is challenged by the potential for variability in terms of numbers of customers, types of customers, areas to be modelled, durations of subscriptions, uptake for renewals, complexity of modelling etc.

A marketing and sales strategy is in place to take the product to market beyond the project and realise revenue opportunities. Channels include:

- conversion of our project stakeholders to clients,
- activities to establish market presence,
- affiliations to develop leads and opportunities,
- bidding and project work,
- advice from domain leaders, and
- traditional marketing activities.

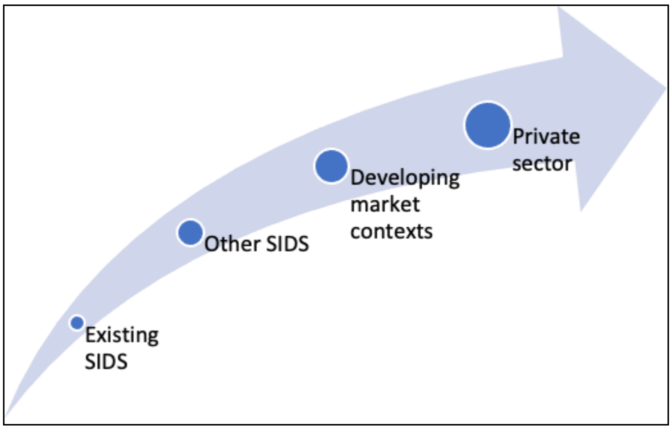



***Figure 21:*** *RE-SAT commercial trajectory plans.*

Two broad categories of users have been identified, these are broadly governmental institutions and private sector organisations. The tables below summaries what each of these broad categories needs and why. RE-SAT contributes to the evidence required by these organisations to address their needs.

| Institutional side | They NEED to: | So…they require EVIDENCE to: |
|---|---|---|
| Energy Ministry | • Reduce fossil fuel imports, cost of energy and GHG emissions | • Support policies, plans and strategies to increase penetration of renewable energy |
| Public utilities | • Maintain supply<br>• Balance supply and demand<br>• Minimise costs | • Plan for generation expansion<br>• Justify expansion and investment |

| Private sector side | They NEED to: | So…they require EVIDENCE to: |
|---|---|---|
| Independent Power Producers | • Understand generation potential and economic risks | • Develop bankable project proposals |
| Energy companies (energy developers) | • Prospect for new plant locations<br>• Develop sustainable energy infrastructure | • Justify site selection<br>• Demonstrate acceptable risks profile for development |

In summary, we are building market presence and developing evidence for application potential.

# 6. Evaluating the results

Our project was set to support the national planning process in Montserrat to contribute to their transition from fossil fuel electricity to renewables. The Renewable Energy target set by Montserrat at the start of the project (2018) was 100% RE penetration by 2020. This target was dependent on the development of the geothermal facilities, which unfortunately has not materialised due to technical difficulties.

The Monitoring and Evaluation approach was based on a common framework which included:

1. M&E Plan – laying out our M&E approach and indicators.
2. Baseline evaluation – assessment of the starting conditions of indicators to be measured.
3. Midline evaluation – assessment of the progress towards targets at midline.
4. Endline evaluation – assessment of the final outcomes and impacts.
5. Cost-effectiveness analysis – quantitative account of why the solution was a cost-effective method of addressing the problem compared to alternatives.

The activities undertaken for these evaluations included:

1. Design: Definition of the Terms of Reference for the endline evaluation, which complements the overall M&E Plan.
2. Monitor: Continual monitoring of progress against Outputs, Outcomes and Impacts.
3. Implementation: Data and information collection through literature review, Working Group meetings, visits, workshops, evaluation interviews.
4. Learning and recommendations.
5. Report writing and acting on findings.

## 6.1. Process evaluation

### Effectiveness

IMPLEMENTATION: The project was delivered effectively through a robust implementation plan and by continual engagement with stakeholders.

> *"You went beyond your objectives from what I remember initially. I think you guys have really improved the platform and you took into account our proposals, changing and tweaking a few of the parameters. It was well done!"* **Lavern Ryan, GIS Specialist (Physical Planning unit)**

PARTNERSHIP ARRANGEMENTS: The Working Groups have been effective in ensuring relevant stakeholders are consulted.

> *"It was useful to have Statistics, having [GIS] and having the different teams as well to show how different departments are required for the implementation of these projects. Having that collaboration was good."* Kenrick Burke, Director of Energy (MCWEL)

MANAGEMENT ARRANGEMENTS: The project is being managed effectively by utilising collaborative working methods within the IEA team and with partners.

> *"Your input and persistence, getting everyone together, engaging us and making sure we all knew what it was about led to some aspect of the project success, it was great."* Lavern Ryan, GIS Specialist (Physical Planning unit)

## Relevance

USEFUL: The RE-SAT project has contributed to Montserrat's journey to renewables.

> *"Because we were able to actually use the tool to do some work and to help us in some of our decision making, it has definitely achieved its objectives … it has assisted us significantly with some of our work that we have done."* Kenrick Burke, Director of Energy (MCWEL)

ALIGNED: RE-SAT is aligned with Montserrat Government strategies.

> *"We have used the RE-SAT platform to actually do a desktop wind study and that helped to inform the information we used for the Energy Task Force. Looking at how we, as an island, implement different technologies it is useful, very valuable.*
>
> *"The critical thing for us was to be able to analyse and have some level of, and estimate, outputs from RE technology based on different locations on the island. RE-SAT helped with that.*
>
> *"The priority we have is to increase level of RE penetration. Having this tool will help us to better planning and estimating, it is quite helpful in that regard."* Kenrick Burke, Director of Energy (MCWEL)

BUILDING CAPACITY: The RE-SAT project successfully built the capacity of stakeholders in Montserrat.

> *"I benefited exponentially from your workshops and training sessions. [The] training session was very helpful, very insightful and made me want to know more. Even though we had to go virtually it was still very hands on and efficient in the ways [the IEA] taught us how to use the platform."* Oswen Carty, Energy Officer (MCWEL)

## 6.2. Impact evaluation

The RE-SAT projects has provided the Government of Montserrat with a new renewable energy platform that has been used to support their transition to renewables and a climate resilient future.

Montserrat has a vision of achieving 100% renewable energy grid penetration by 2030. The first step towards this has already been achieved through the 250kW utility scale rooftop solar project across several buildings in Brades. This is providing 10% of the grids' peak daytime demand. The second phase, an additional 750kW of solar plus battery storage, will collectively provide 40% of Montserrat's daytime peak electricity load. To go beyond this, Montserrat is developing plans to ensure the electricity system can operate reliably.

The target of 100% was based on information provided from the 2010 geothermal study[4], and an Early Market Engagement exercise in 2017 to procure a 2.5-5MW geothermal plant which would satisfy 100% of the Montserrat energy requirement. Due to political factors outside of the scope and beyond the control of the RE-SAT project, the drilling of the third well was not completed.

To aid in planning the development of the renewable energy sector, Montserrat has used RE-SAT for some specific applications to test the performance of different combination of renewable energy installations. The IEA provided face-to-face training, assistance by video conference and practical workshops on how to use the RE-SAT platform to support Montserrat in its transition towards renewable energy. Some examples of use are detailed in the following sections.

### 6.2.1. Testing the alternative Integrated Resource Planning

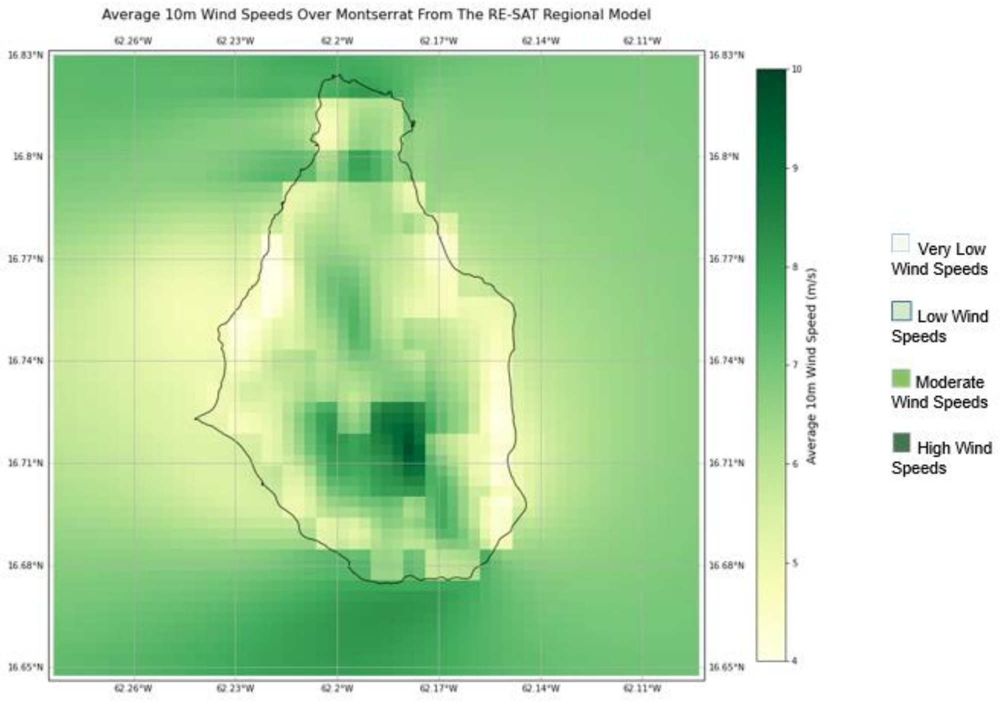
The Government of Montserrat commissioned an Integrated Resource Plan (IRP) with a consulting engineering and project implementation organisation to create a renewable energy strategy. An Energy Task Force was created in Montserrat, which included the Energy Unit of MCWEL, the Program Management Office in Montserrat, MUL and a Blue Economy consultant, that was charged with the creation of an alternative IRP.

Using RE-SAT, the capacity factors from scenarios for 4MW of wind energy production from 6 sites were used in the MCWEL alternative IRP. These internal calculations were used to check the preliminary results from the IRP consultants, to check the values were indicative of what is expected on island. The RE-SAT results were similar to the IRP findings, with variation within the tolerance level required. The Energy Unit were not advised of the software used to calculate the capacity factors used by the consultants.

[4] https://publications.mygeoenergynow.org/grc/1030310.pdf

### 6.2.2. Wind resource evaluation using RE-SAT resource maps

Two wind turbines were installed at St. Georges Hill in the late 1980s and 1990s (215 kW)[5]. However, this small wind farm suffered damage during a hurricane and volcanic activity. Whilst not operational, the physical structures are still evident and have resisted the harsh surrounding conditions. Although wind energy has not yet been fully re-explored in Montserrat, a desktop study using RE-SAT wind resource maps was conducted to determine suitable locations for the implementation of wind energy. The outcome of this study was included in their first Environmental Statistics Compendium[6] in Montserrat, which was published in 2020. This Report was prepared by the Statistics Department in Montserrat, which was one of our partners within the government.



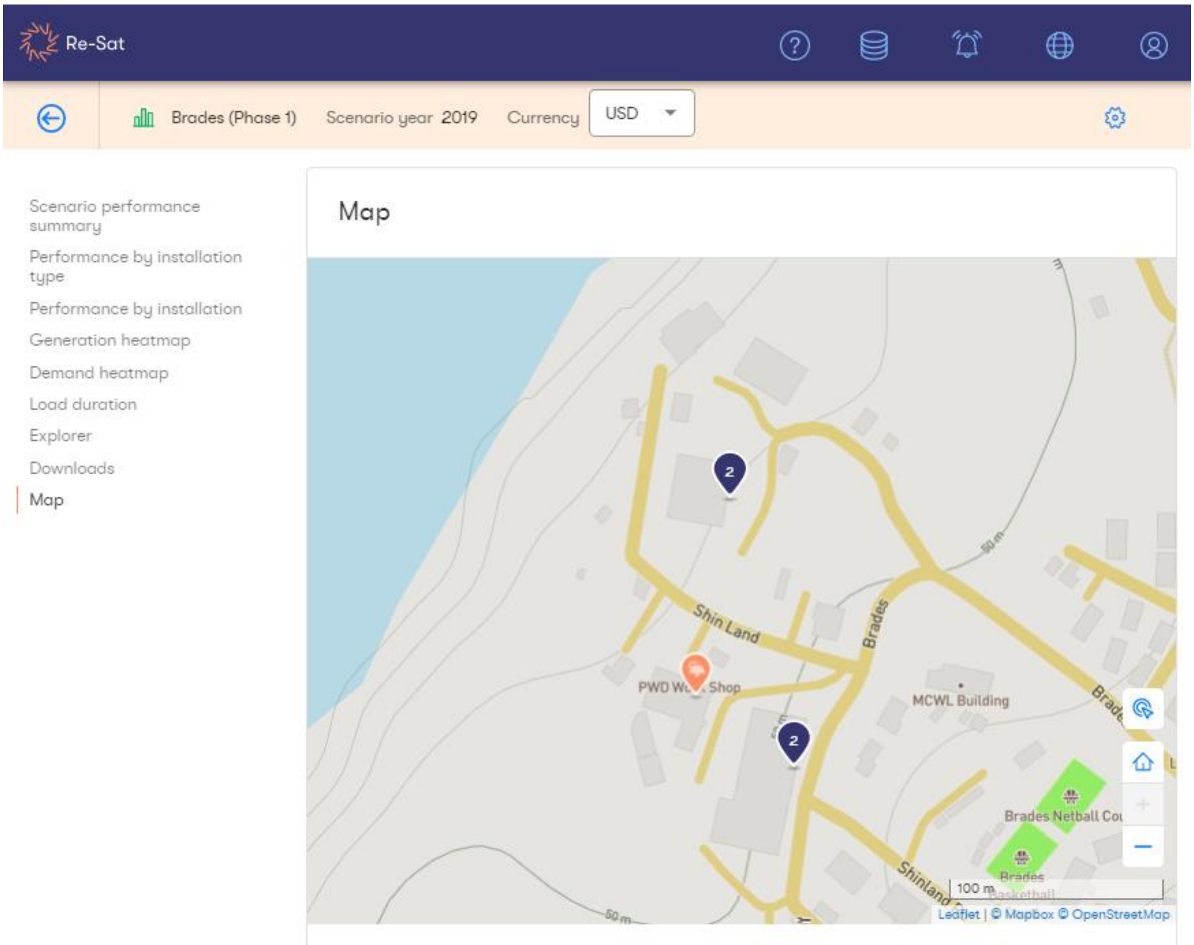

Source: RE-SAT energy analytics platform, developed by the Institute for Environmental Analytics (IEA).

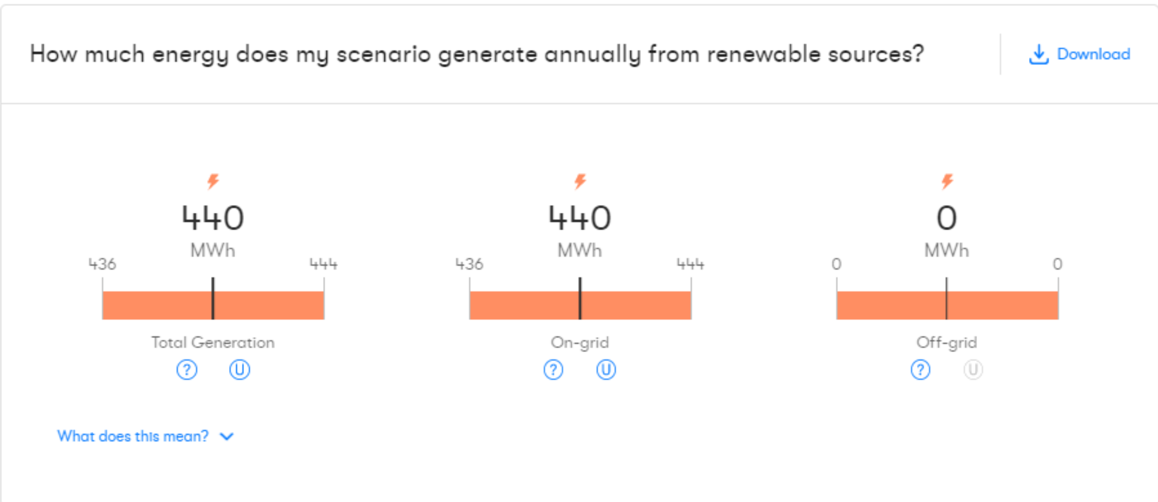
The map, included in the Compendium, shows the average 10m wind speed over Montserrat, for the period 2013-2018. The map was generated by the IEA using a high-resolution weather model and available from the RE-SAT energy analytics platform. The model had been refined and validated using weather data collected from the Montserrat Volcano Observatory and the John Osborne Airport. The different shades of green represent the different average wind speeds that are experienced in different areas on the island. White to very light green represents very low average wind speeds whilst dark green represents the highest average wind speeds. According to the map high wind areas in Montserrat include Geralds, Lookout and Soufrière Hills.

[5] Wright. R. (2001): Wind energy development in the Caribbean. *Renewable Energy*, vol 24, issue 3-4, 433-444 http://aceer.uprm.edu/pdfs/wind_energy_caribbean.pdf
[6] 2020 Environmental Statistics Compendium (2015-2019), Statistics Department, Montserrat https://statistics.gov.ms/wp-content/uploads/2021/01/2020-Environmental-Compendium-2015-2019-Series..pdf

### 6.2.3. Testing the current renewable energy configuration with RE-SAT

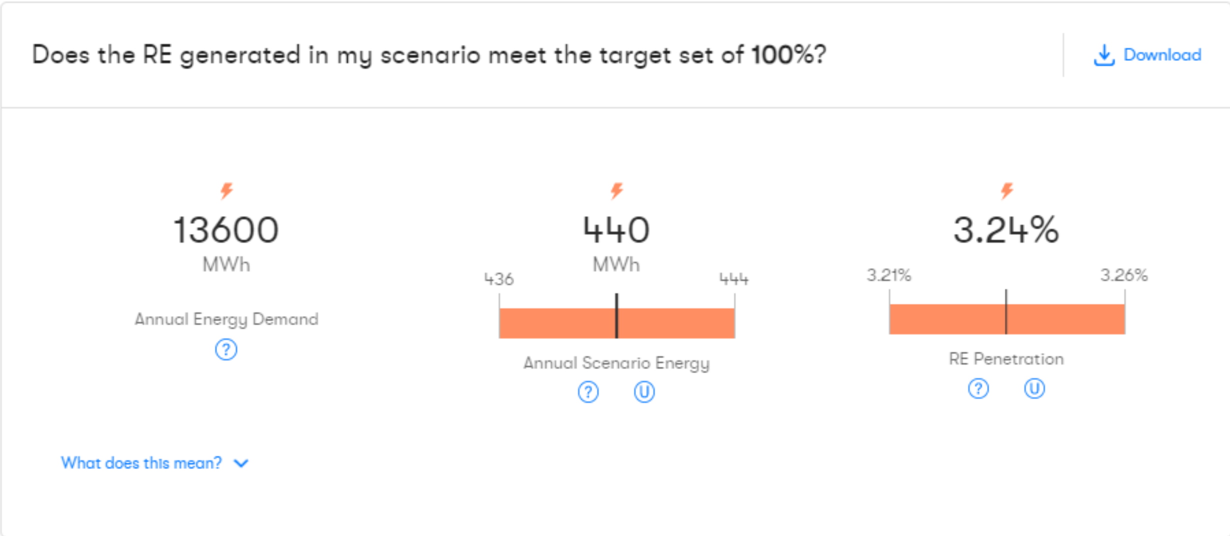
The performance of RE-SAT was tested by creating a scenario of the current renewable energy installations in Montserrat (250kW Solar PV systems (Phase 1) in Brades).



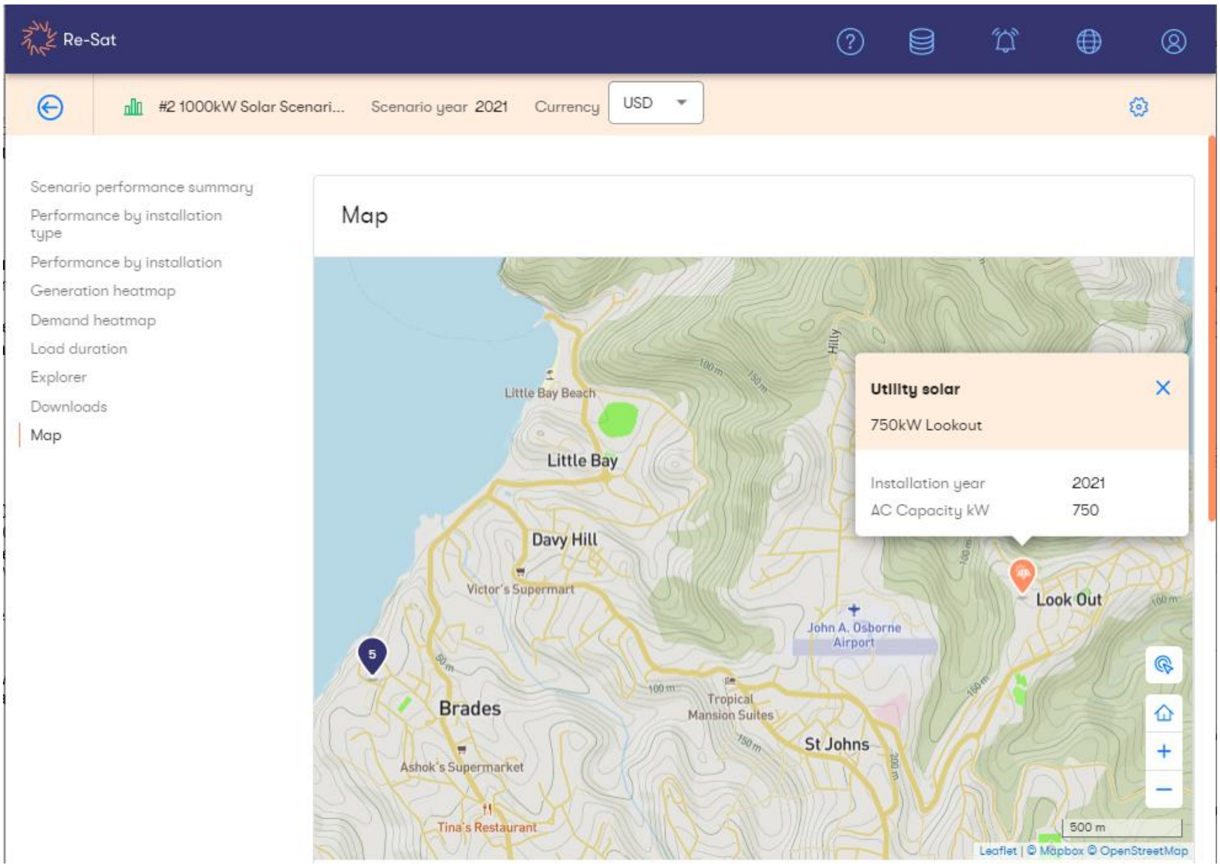
The scenario simulated by RE-SAT generated an annual energy average of 440MWh, which compared very well with the 2020 observed annual averaged production of 462MWh (figure provided by the Ministry). The slight lower production simulated by RE-SAT is considered as a positive feature, as lower conservative estimations are preferable.

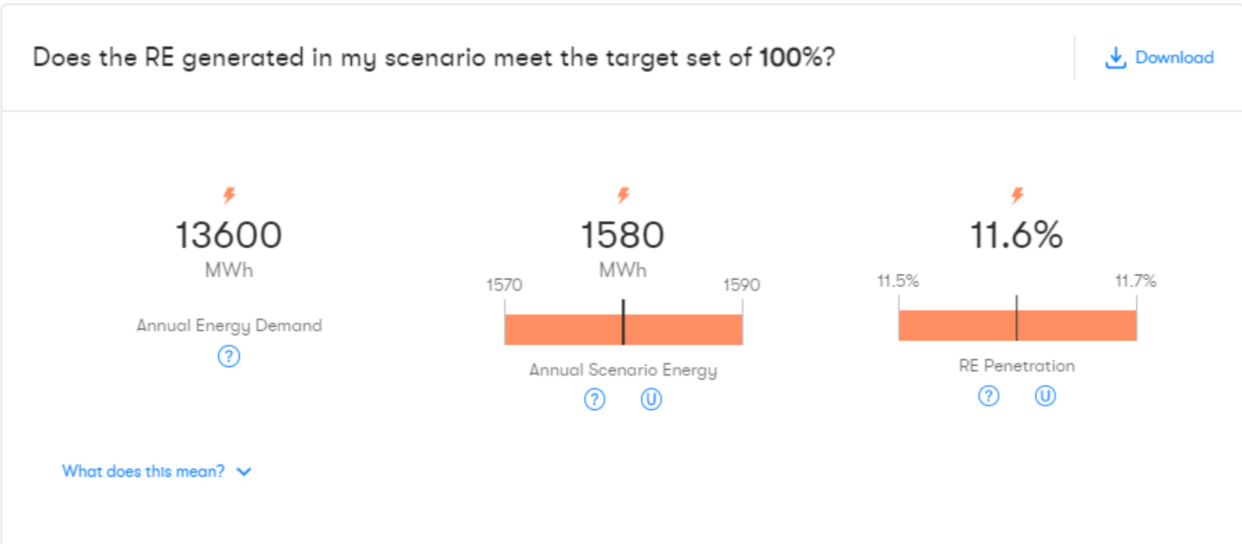
RE-SAT also calculates what percentage of the annual energy demand is met by the renewable installations simulated in the scenario. In other words, it calculates the renewable energy penetration achieved by any combination of installations as defined in the scenario. The current annual energy demand in Montserrat is 13600 MWh, therefore the Phase 1 solar PV project represents a 3.24% penetration of renewables.




Another important metric that RE-SAT calculates is the fuel volume, cost and CO2 equivalence that the renewable energy generated represent. RE-SAT assumes a liner conversion of the renewable energy generation to the equivalent quantity. With this in mind, the Phase 1 solar project is saving almost 30 k gallons of fuel and around 335 tonnes of CO2 per year.

Exploring the addition of Phase 2 (750 kW) solar project, the renewable energy penetration in Montserrat increases to 11.6%


Re-Sat
#2 1000kW Solar Scenari...
Scenario year 2021
Currency
USD
Scenario performance summary
Performance by installation type
Performance by installation
Generation heatmap
Demand heatmap
Load duration
Explorer
Downloads
Map
Map
Utility solar
750kW Lookout
Installation year 2021
AC Capacity kW 750
Little Bay Beach
Little Bay
Davy Hill
Victor's Supermart
Brades
Ashok's Supermarket
Tina's Restaurant
John A. Osborne Airport
Tropical Mansion Suites
St Johns
Look Out
500 m
Leaflet | © Mapbox © OpenStreetMap

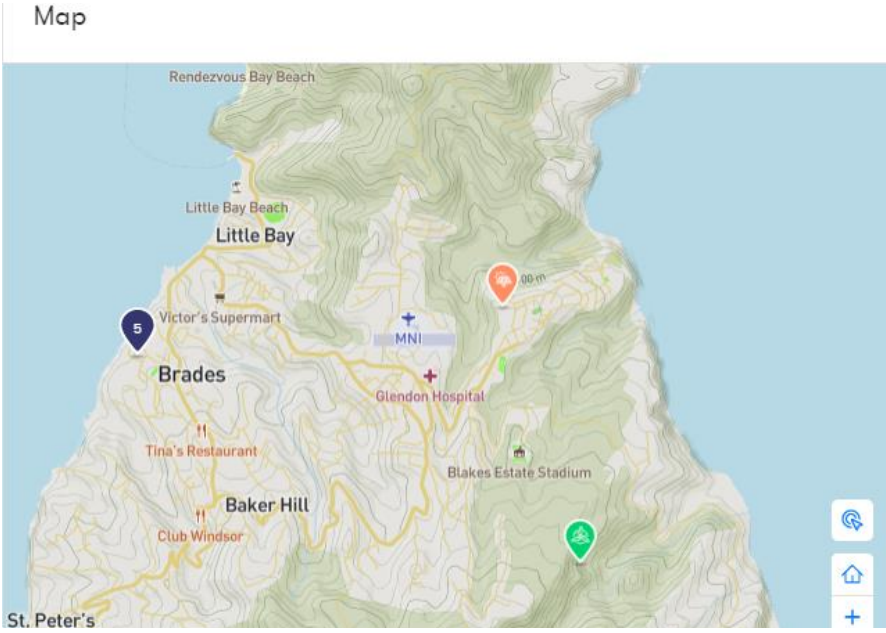

Does the RE generated in my scenario meet the target set of 100%?
Download
13600
MWh
Annual Energy Demand
1580
MWh
1570
1590
Annual Scenario Energy
11.6%
11.5%
11.7%
RE Penetration
What does this mean?

### 6.2.4. Exploring potential renewable futures using the RE-SAT platform

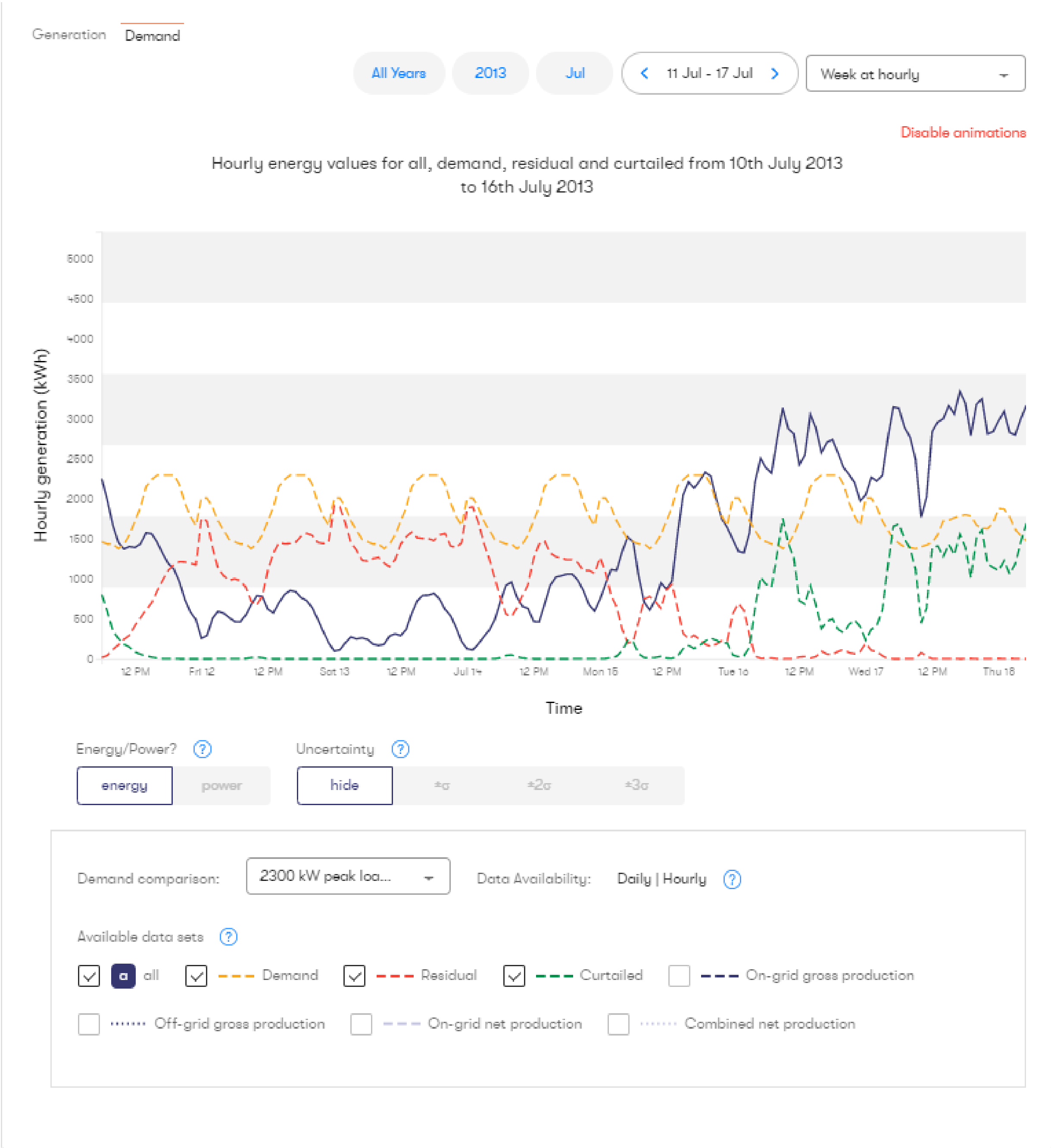
The price of electricity in Montserrat is about 0.3 USD per kWh which, according to Montserrat Utilities Limited, is one of the highest in the region. Almost half of this can be attributed to the fuel surcharge. Importing expensive diesel for power production is causing high electricity bills, which increases the cost of living in Monserrat and reduces the attraction of energy-intensive business to invest in Montserrat. Therefore, exploring potential renewable futures is an economic imperative for Montserrat and RE-SAT is supporting them on their journey.

#### A. Existing PV solar projects (1MW) plus a 4MW wind farm – Scenario for 2023

For this scenario, the energy generated exceed the demand, which was assumed to increase to an annual average of 15.6 GWh by the year 2023.




RE-SAT assumes that if renewable energy generation exceeds the demand curve at any timestep, the excess renewable energy is curtailed (lost). That is what happened in this scenario. The graph shows an example week in July when generation (blue line) suddenly exceeds demand (yellow line) around the middle of the week. Curtailment (green line) starts to happen and the need for energy being produced by other sources (residual, red line) is close to zero. This analysis can give an indication of the amount of energy that might need to be stored and perhaps use the data to inform further analysis for battery storage.



## B. Exploring geothermal power generation with RE-SAT

Exploiting a potential geothermal resource has been an objective of the Government of Montserrat for many years and was incorporated into both the island's Sustainable Development Plan 2008-2020 and Energy Policy. High level of investment and risks are associated with prospecting for geothermal, but the UK government agreed back in 2011 to fund the drilling of two wells as the exploratory stage, which have proven capacity to support the energy needs of Montserrat. Unfortunately, a geothermal plant has not been installed so far for various reasons, but the government of Montserrat remains committed to integrating several renewable sources on the grid, including wind, solar and geothermal.

Because of this, the contribution of geothermal power can be added to RE-SAT by treating it as an installation with a fixed output or predetermined time-series of values provided by the user. Together with geothermal, hydropower and biofuel are the other two renewable energy sources that the platform can add contributions from as "scheduled generators".

## Summary

**These exercises were the initial attempt to model potential future scenarios to reach the target of 100% renewables. These scenarios can be used as a starting point and adjusted by exploring other sites, sizes and types of installations, to reach a better generation mix.**

**Using RE-SAT has made it very easy for Montserrat officials to assess different scenarios for potential renewable installations, especially the realisation that Montserrat's natural resources have the potential of achieving its 100% target, mainly through a combination of solar, wind and potentially geothermal.**

Montserrat has now a common platform for officers in different department to use common data and analytics for efficient and effective collaboration and decision-making.

> *"Going forward in the future, [RE-SAT] will help us to compare different RE technologies so if we have 2 projects, we want to compare from an output standpoint and even from a financial standpoint, the tool itself can actually assist with that which is something that is quite valuable to us."* Kenrick Burke, Director of Energy (MCWEL)

According to the Director of the Energy Unit in Montserrat, existing methods for obtaining energy generation potential would have been best guess estimations, utilising existing stakeholder knowledge and MS Excel to give a "*broad, tentative estimation based on assumptions*"[7]. It was noted that this would have taken much more time and would not have been as accurate as the results provided using RE-SAT.

[7] Quote from Kenrick Burke during Day 2 Session 3 of Virtual Visit 3 on 30th June 2021.

# 7. Lessons learnt

The main learnings relating to our engagement with in-country partners, the technical challenges encountered, and the implementation of RE-SAT are presented here and are common to all SIDS. Some specific leaning remarks to highlight aspects relevant to Montserrat are also included.

## In-country challenges:

- Timing and relevance are important for co-production: The RE-SAT project was well received by Montserrat due to their ambitions to transition to renewables as they saw an immediate opportunity to exploit the platform to their advantage. (Montserrat Energy Policy 2016-2030).
- In-country commitment is vital for the success of partnership projects: The lead partner in Montserrat, the Energy Unit at the Ministry for Communications, Work, Energy and Labour (MCWEL), facilitated the engagement with other organisations.
- There is a lot of competition for workshop time in the recipient SIDS: Many nations and suppliers are operating in Montserrat, and given the small size of the nation, officials are engaged in several project which compete for their time. Feedback received from partners confirmed that our workshops were fun and informative compared to others.
- Data and knowledge sharing is essential for the development of tailored products in countries. The power data shared by MCWEL, and geographical information shared by the Physical Planning office were crucial for the validation and calibration of the tailored RE-SAT application in Montserrat.
- Local capacity to receive knowledge transfer varies across countries and therefore delivery methods need to adjust accordingly. For some of the organisations involved in Monserrat, learning about renewables was a new concept, but they reported gaining understanding and knowledge due to our project.

## Implementation challenges

- Establishing a clear management and working structure (internal and external) from the start makes everyone within the partnership know their responsibilities within the project. The establishment of the Working Group in Montserrat was welcome and crucial for the co-development of the platform that is fit-for-purpose in Montserrat.
- Testing different ways of engaging with our stakeholders and prompting following up with partners was welcome. Relying only on email communication was not effective, therefore the IEA team utilized WhatsApp in Montserrat, following advice from partners which yielded faster responses.

> *"We really did appreciate that in addition [to monthly meetings] you were always keeping on top on us with WhatsApp etc. We really did appreciate it."*
> **Jasmine Jno-Baptiste, Social Statistician (Statistics Department)**

- Capacity building was challenging during the pandemic and has limited the delivery of value. Less participants attended the virtual training workshops compared to the face-to-face workshops that we held in Montserrat, reducing the impact of the project. Even though the sessions were shorter, we could not have ad-hoc meetings, external conversations and presentation to others within the country, which are very important for impact, awareness raising and sustainability.
- The community of practice was a welcome addition to share knowledge among the Island States. Montserrat contributes a few articles to the Community Newsletter and used its content for their own renewable energy awareness raising.

## Technical challenges

- Estimating uncertainty of power production is a complex process. It is believed that the quantification of uncertainty is a unique capability for RE-SAT and may be a compelling feature in the commercial marketplace although more market testing is currently being carried out to confirm this.
- Scalability is important for the commercial future of RE-SAT. Scalability of processing resources is now understood to be a critical requirement and we are migrating the system to a more flexible Web Services provider to address this.
- Preparation for version release and training workshops. A robust procedure for application version release and training is now in place to ensure application updates work at time of release and material is ready on time for training.
- Weather data preparation evolved during the project, and we now have a robust and efficient workflow to produce these datasets ready for our commercial phase. Different configurations of the weather model have been tested and new procedures to gain efficiencies in our processes implemented. In particular for Montserrat, the scale of the island allowed the project to test the feasibility of creation of a 330m x 330m weather dataset. This is the highest resolution weather dataset successfully simulated by the RE-SAT project and confirm the feasibility of this scale for future applications.
- The addition of the contribution from other non-variable renewable energy generation (geothermal, hydro and biomass) in RE-SAT adds value to the platform. The Montserrat requirement to include geothermal production in some scenarios was the first example of the requirement of the addition of user specified power generation series and confirmed the feasibility of this capability in RE-SAT scenario planning.
- A new user journey has made the application more intuitive and user friendly. A UX (User Experience) consultancy specialist was sub-contracted mid project to advice on application user interface design. This was very valuable and in future would be commissioned earlier in the project lifecycle.

Delivering value from big data

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