RE-SAT: Energy Analytics Platform

Renewable Energy planning in Saint Lucia

Case study

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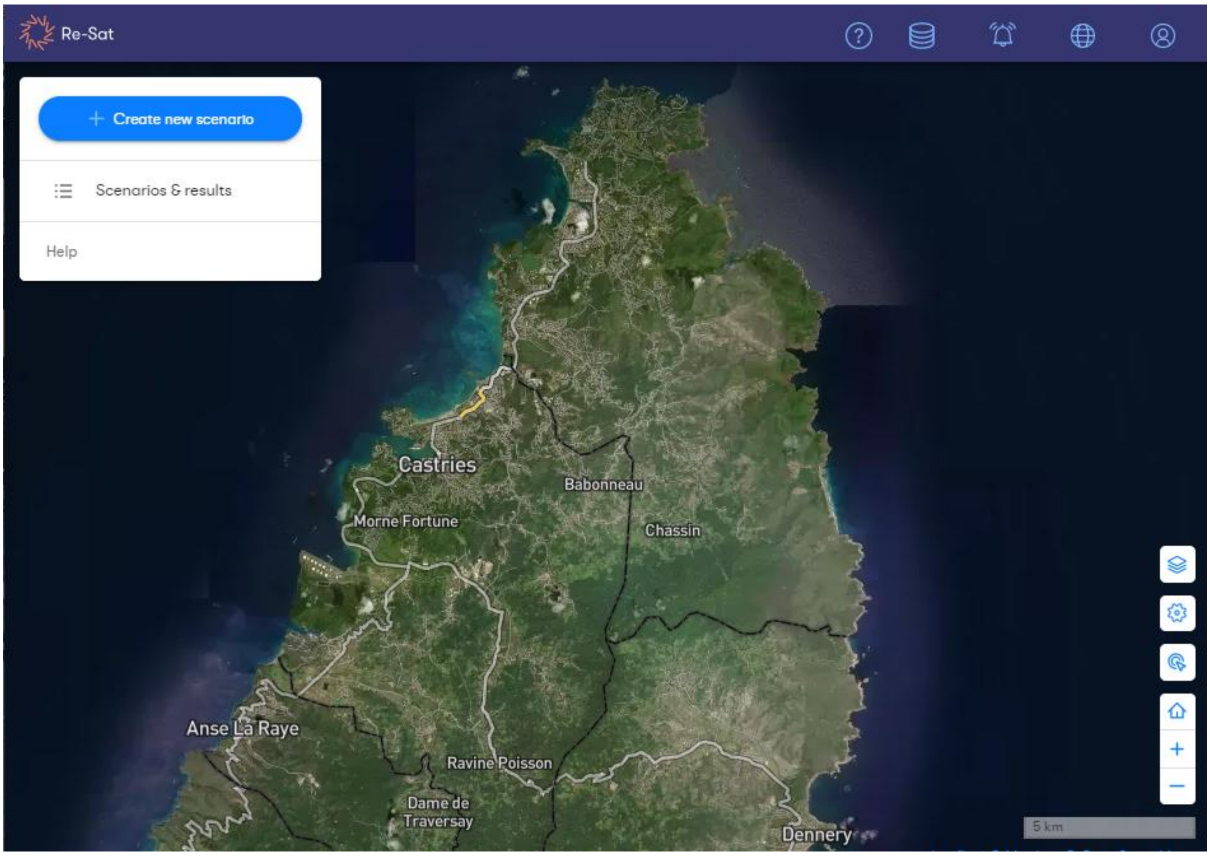

The Institute for Environmental Analytics (IEA)

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 Saint Lucia acknowledges the assistance from the Ministry for Infrastructure, Ports, Energy and Labour, the Department of Sustainable Development, the Meteorological Service, the National Utilities Regulatory Commission (NURC) and the Organisation of East Caribbean States - OECS

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 Saint Lucia 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.

[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.

   d. CO_2 and fuel saved – RE-SAT calculates the CO_2 saved and amount fossil-fuel displaced (and related costs) by the modelled RE installation.

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 Saint Lucia** was led by the Ministry for Infrastructure, Ports, Energy and Labour (Energy unit and Public Utilities unit). Other government departments and agencies included: the Department of Sustainable Development, the Meteorological Service, the National Utilities Regulatory Commission (NURC) and the Organisation of East Caribbean States (OECS).

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 Saint Lucia in July 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 Saint Lucia after the funded project ends was also included.

The **performance of the RE-SAT platform in Saint Lucia** was tested against actual power produced by a solar PV arrays installed at Ministry of Infrastructure carport. The errors, expressed as a percentage of the installed capacity measured on the 15-minute average power accounted to 11% and when averaging over a day the error is reduced to 2%.

Using RE-SAT has made it very easy for Saint Lucia officials to assess different scenarios for potential renewable installations. An **early impact** when exploring different scenarios with RE-SAT was the realisation that by adding the 15MW geothermal plant in combination with the exiting installations and a new solar and wind farm, the target of 35% RE by 2025 was not only achievable, but surpassed.

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.

"This platform will definitely be very useful as we go forward in terms of planning and looking at certain projects that we are looking at, and how it will impact on our projected targets, and paving the way forward for our electricity distribution stabilisation for Saint Lucia. So, I feel that the platform will definitely be a plus and can be one of the tools in our toolkit going forwards for Saint Lucia." Fabian Lewis, Public Utilities Officer (MIPEL)

"It is clear how much renewable energy capacity we want to put in to achieve our targets. But we know that all of that is based on what the weather conditions are like, so I could say that I am going to put down 12MW but that does not exactly mean that I am going to get 12MW in say 2- or 3-years' time. Having that information embedded in the platform gives us the added benefit to be able to model out and see if what we are saying is actually realistic or if we have to make some allowances to increase the amount of solar or increase the amount of wind that we want in a specific year to achieve our target." Kurt Inglis, Public Utilities Officer (MIPEL)

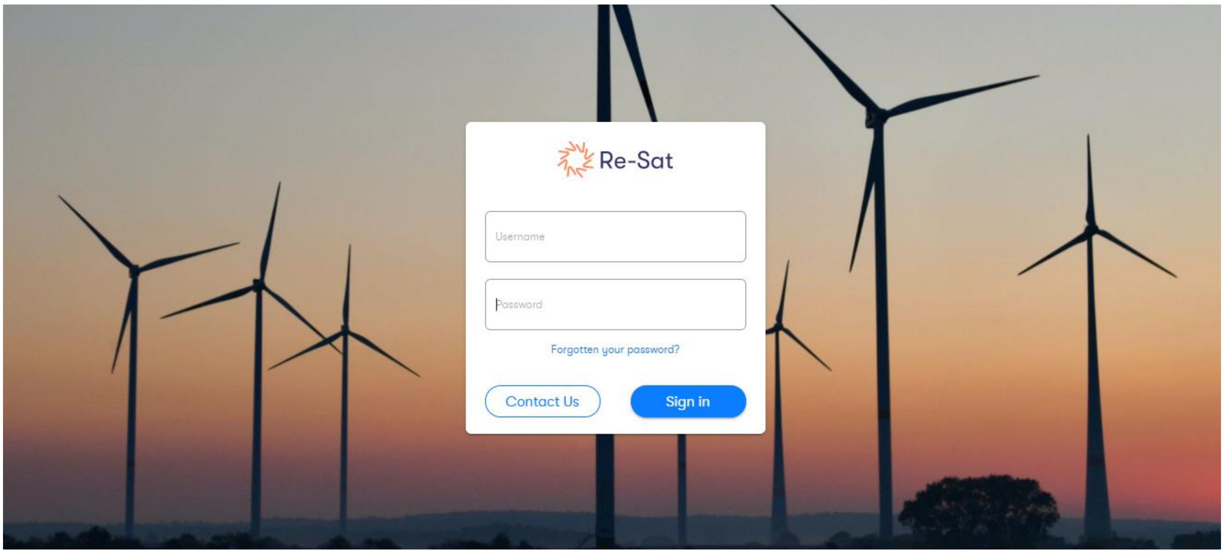

***Figure 1**: Landing page of the RE-SAT platform.*

2. Project overview

2.1. The energy and data challenges facing Saint Lucia

2.1.1. About Saint Lucia

Saint Lucia is one of the six countries that make the Windward Islands and is located in the southern arc of the Lesser Antilles. Saint Lucia is 43 km long with a maximum width of 23 km, covering an area of 617 km2, with a population of around 180,000. Castries is the capital. The island is of volcanic origin being within the crater of an ancient volcano called Soufriere. Boiling sulphur springs contain substantial energy potential.

Saint Lucia is a member of CARICOM (Caribbean Community) which aims to promote economic integration and co-operation among its members. Saint Lucia is also a member of the OECS (Organisation of East Caribbean States), an inter-governmental organisation dedicated to economic harmonisation, integration and protection of human and legal rights among the countries in the Eastern Caribbean.

Figure 2: *Map of Saint Lucia.*

2.1.2. Electricity in Saint Lucia – Energy targets

Saint Lucia's electricity supply is nearly 100% reliant on imported fossil fuel. In 2010 the government developed the Saint Lucia National Energy Policy[2] outlining the plans to increase the use of renewable penetration. The targets were to achieve at least 5% by 2013, 15% by 2015 and at least 30% by 2020. These targets were reviewed in 2015 and new targets submitted under the Intended Nationally

[2] Saint Lucia National Energy Policy (2010). http://www.oas.org/en/sedi/dsd/Energy/Doc/NEP_StLucia_web.pdf

Determined Contribution (INDC)[3] under the United Nations Convention on Climate Change (UNFCCC). The new targets for electricity generation are: 35% renewable energy target by 2025 and 50% by 2030 based on a mix of geothermal, wind and solar energy sources. Saint Lucia has submitted updated NDC in January 2021

In 2016, Saint Lucia created the National Utilities Regulatory Commission (NURC) to oversee and regulate the electricity system. In 2016 a National Energy Transition Strategy and Integrated Resource Plan (NETS)[4] was developed by Saint Lucia Electricity Services Limited (LUCELEC) and the Government of Saint Lucia. This strategy suggested that a combination of solar, wind and diesel together with energy storage might be the best combination for Saint Lucia and might achieve approximately 40% renewable energy penetration.

The national power company, LUCELEC, currently houses 10 generators with an available capacity of 86.2 MW, with a peak demand of around 60MW. Annual load is expected to grow at an average of 1.43% over the next five years. Figure 3 display some of the statistics from LUCELEC Annual Report.

Figure 3 *: Some statistics from LUCELEC Annual Report[5] (2019)*

In common with many Small Island States, Saint Lucia 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.

The Government of Saint Lucia believes a well-functioning electricity system underpins a strong national economy and is committed to ensuring that all citizens have safe, reliable, and cost-effective access to electricity.

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3 Saint Lucia Intended Nationally Determined Contribution. (2015). https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Saint%20Lucia%20First/Saint%20Lucia%27s%20INDC%2018th%20November%202015.pdf

4 Saint Lucia National Energy Transition Strategy and Integrated Resource Plan. http://www.govt.lc/media.govt.lc/www/resources/publications/saint-lucia-nets-executive-summary-final.pdf

5 LUCELEC Annual Report (2019). https://www.lucelec.com/sites/default/files/documents/LUCELEC-2019-Annual%20Report.pdf

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 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 Saint Lucia, 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.

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[6], 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".

> *"We will be able to add our load curves, use the platform to better reflect our situation going forward. Being able to have that is a plus for us, and we will be able to put that in to use to model our updated NDC."* **Kurt Inglis, Public Utilities Officer (MIPEL)**

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).

[6] IRENA: International Renewable Energy Agency

3. Project partners

Our lead partner in Saint Lucia is the Ministry for Infrastructure, Ports, Energy and Labour (Energy unit and public utilities unit). Other government departments and agencies involved in the project included the Department of Sustainable Development, the Meteorological Service, the National Utilities Regulatory Commission (NURC) and the Organisation of East Caribbean States (OECS)

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.

Figure 4*: Saint Lucia project partners during Discovery visit (March 2018).*

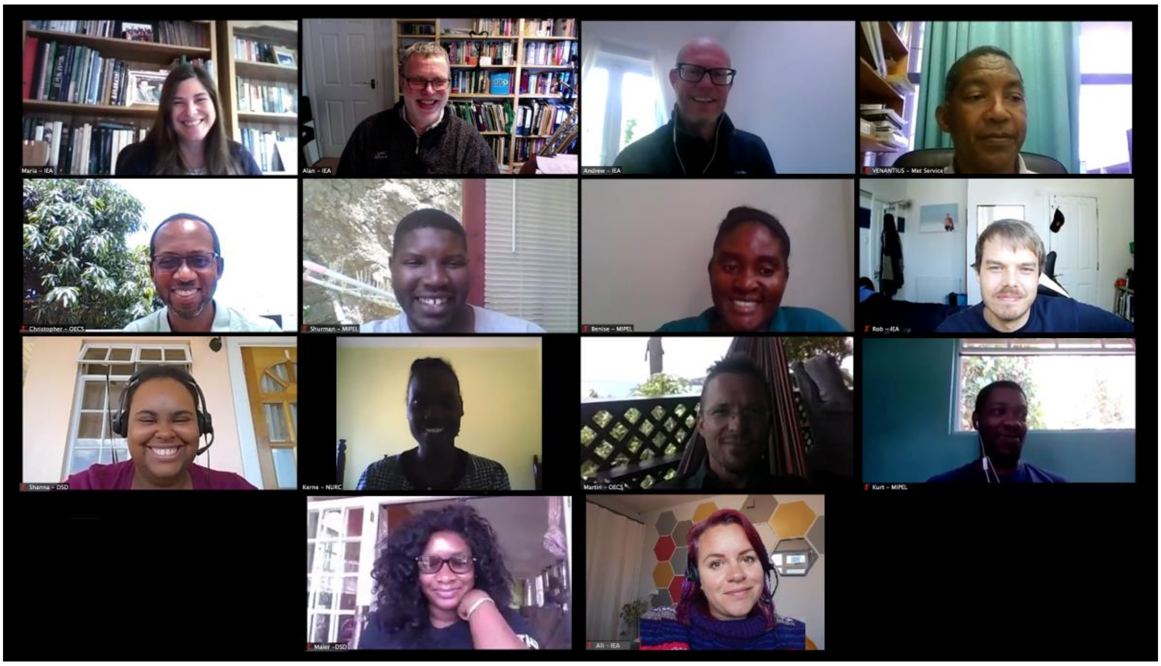


Figure 5*: Saint Lucia participants and IEA members during our virtual visit in May 2019*

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

What RE-SAT does:

- Verify and extend **national RE resource assessments** whilst **quantifying uncertainty**;
- Create representative time series of wind and radiation from **weather simulations** enhancing **scarce local observations with earth observation data** and **regional weather modelling**
- Develop methods to assess the **suitability of locations** for renewable energy production;
- Allow policymakers and planners to **assess the energy production potential** of future renewable energy production mixes.

This means that energy planners can:

- Increase the coverage, resolution and precision of **estimates of natural energy resources**;
- Increase the confidence in **RE estimates for investors** and planners by **quantifying risk**;
- Benefit from **more skilled staff working on RE planning** in the SIDS; and
- Improve the **cost effectiveness** of creating estimates of RE production given **scarce data resources.**

This ultimately benefits the SIDS by:

- Increasing the **uptake of RE** in the SIDS assisting in the **reduction of carbon emissions**
- **Reducing the costs** of:
    - project finance
    - implementation
    - energy production
- **Reducing the economic risks** of reliance on fossil fuels.

Figure 6: RE-SAT intended value chain.

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

<table>
<tr><th>High level Requirement</th></tr>
<tr><td>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.</td></tr>
<tr><td>Weather data - Quantify the expected variation in weather variables affecting energy production by location over a simulated time period.
The simulated weather variables will:
• Range over multiple years (sufficient to capture modes of multi annual variation e.g., ENSO).
• Reproduce as far as possible the climatology for each nominated location.
• Preserve realistic meteorological inter-area correlations.
• Provide simulated data points at nominated time resolutions with no missing gaps, at a nominated spatial resolution.</td></tr>
</table>

High level Requirement
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: • 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.
Power output estimation Create future scenarios for power output from new RE installations, required for: • Strategic planning. • Response to national communications to the UNFCCC. • Procurement exercises for RE or grid infrastructure. • Support proposals for new infrastructure. Users need to be able to: • Load pre-selected site locations for installations. • Load existing installation specifications into a scenario. • Locate installations 'by hand' on a map. • Define the technical specification of wind and solar installations, sufficient to allow estimates of power production from simulated realistic weather conditions. • 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). • 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. • 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. • Quantify the uncertainty of given levels of energy generation for installations in a scenario, known as exceedance probabilities P10, P50 and P90. • 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). • Allow variations on scenarios at different points in time to be easily developed, compared and evaluated, accounting for installation aging and changes in demand. • Allow users to collaborate by sharing and developing scenarios within and between stakeholder teams.
Training and knowledge sharing • Deliver training to nominated users on how to use the data products and software platform. • Provide a way to exchange knowledge within the country and across countries regarding the use of RE-SAT and renewable energy related issues.
Access to RE-SAT • Provide secure access to the platform, through unique logins to key stakeholders.

4.2. Specific requirements in Saint Lucia

The following specific requirements were requested by stakeholders in Saint Lucia.

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.

Carbon emission displaced

- Requirement to calculate the amount of fossil fuel and carbon emissions displaced by renewables.

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. Saint Lucia had performed a feasibility study for the potential for geothermal power around the Soufriere. The World Bank has now approved funding for geothermal energy exploration in Saint Lucia (July 2021).

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 Saint Lucia 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 Saint Lucia, 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 Saint Lucia and developed a set of agreed targeted objectives with short-term benefits for Saint Lucia as well as long-term benefits.

The RE-SAT functional requirements, as developed in consultation with Saint Lucia 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 (1km x 1km) numerical weather model configured by the IEA for Saint Lucia. They include wind speed, incoming shortwave radiation, temperature, and Global Horizontal Irradiance (GHI). A wave dataset was also generated directly from the 30km x 30km 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 7).

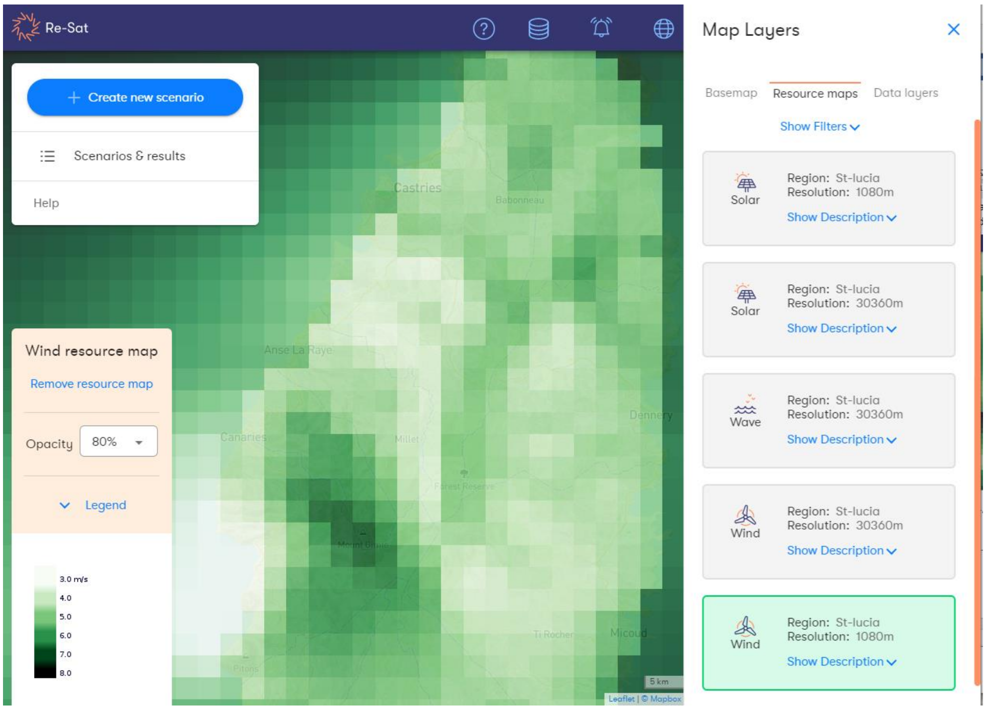


***Figure 7**: Wind resource map for Saint Lucia*

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 Saint Lucia, the following GIS layers are available: buildings, forests reserves, rivers, roads, schools and topography.

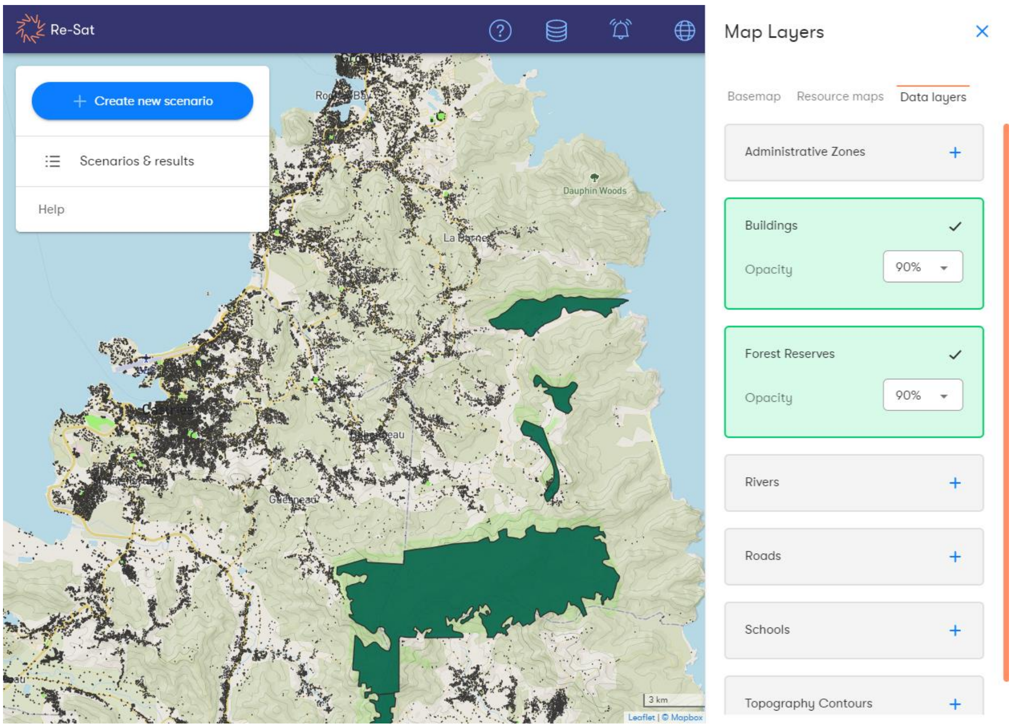


***Figure 8:** Example of some of the GIS layers available in the RE-SAT platform for Saint Lucia.*

4.3.2. Platform capabilities and features

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

2. Renewable scenario settings and installations characteristics: 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. Variable Renewable Energy simulation (VRE simulation): 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 Saint Lucia.

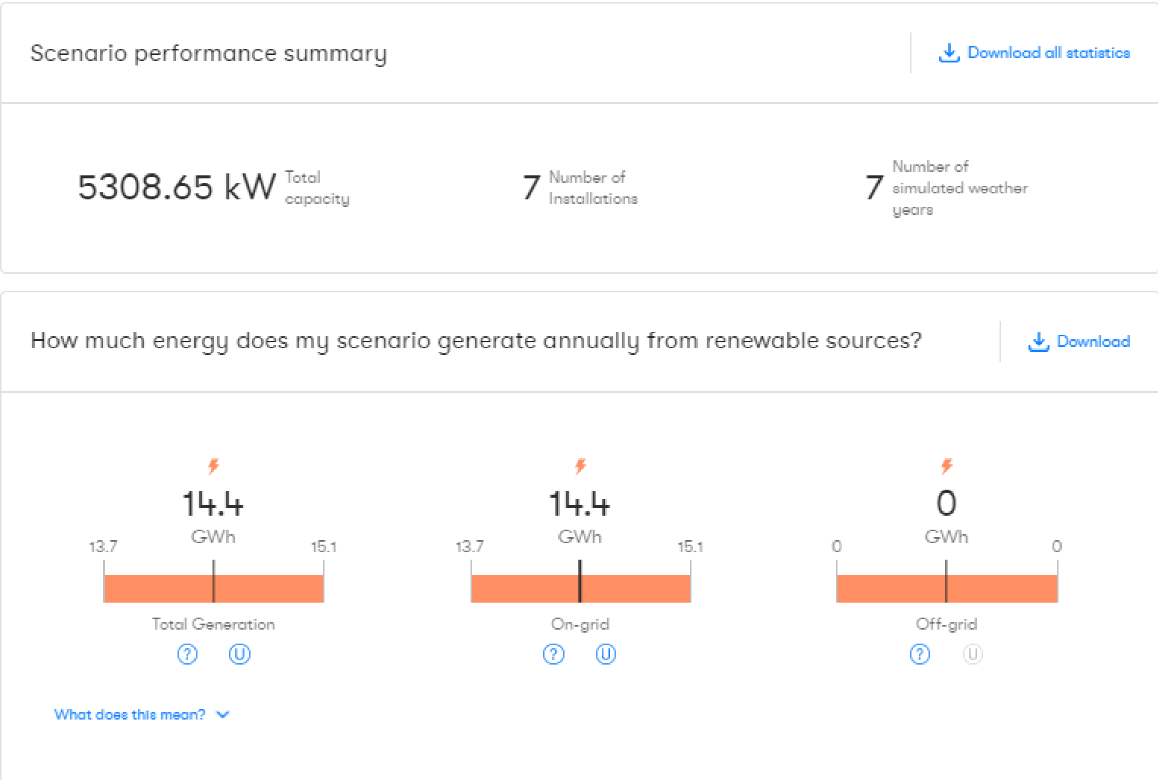


Figure 9: Example of the scenario performance summary display in RE-SAT.

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.

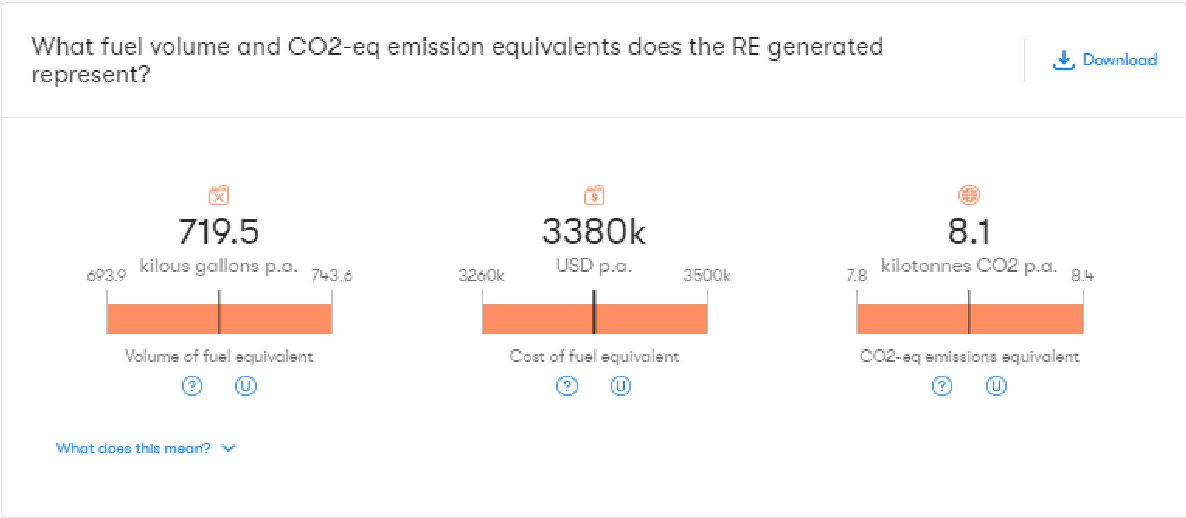


Figure 10: Example of the results of the CO2 and fossil fuel displacement calculations in RE-SAT.

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 11: 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 Saint Lucia and arrived at in consultation with partners.

   Figure 12 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 12**: 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 13: Examples of results exploration capabilities in RE-SAT (Generation Heatmap and Demand Heatmap).

Figure 14: 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.

When you look at the platform (this goes back to what I was saying earlier) I feel that almost every project we are looking at, we may be able to use the platform in one way or another. I see various potentials and opportunities for it to be utilised, and there are probably some that I have not yet in my mind's eye seen yet. I see lots of potential in it, it can be used with other projects." Fabian Lewis, Public Utilities Officer (MIPEL)

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 13 users in Saint Lucia have access to the platform.

> *"The continued engagement and training from your team has definitely been one of the key factors. You have the training documents, collaboration and workshops for capacity building."* Kurt Inglis, Public Utilities Officer (MIPEL)

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:
    - Nationally Determined Contributions - Quantifying the extent to which renewable energy projects can contribute towards more ambitious Nationally Determined Contributions.
    - Integrated Resource Plans - Developing strategies for ensuring future supplies of electricity as part of integrated resource (and resilience) planning.
    - National Energy Transition Strategies - 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.
    - Site selection - 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.
    - Generation profiles - 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.
    - Portfolio effects - The ability to model single installations or complex combinations of different plants in different locations supports the exploration of potential portfolio effects.
    - Investment cases - The platform provides a comprehensive suite of energy metrics that can support the development of robust investment cases and more bankable project proposals.
    - Proposal assessment – 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.

> *It goes without saying, it raised the capacity, that's a definite!"*
> Fabian Lewis, Public Utilities Officer (MIPEL)

4.5. Validation exercise - how does RE-SAT perform in Saint Lucia?

The RE-SAT platform was used to simulate the power produced by the existing solar arrays installed at the Ministry of Infrastructure carport. These total 54kW of generation capacity. The output from RE-SAT was compared with the actual power produced by the installation for October 2019. The power data was kindly provided by the Government of Saint Lucia.

***Figure 15**: Solar carport facility at the Ministry of Infrastructure, Ports and Energy (Union, Castries)in Saint Lucia.*

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 16 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.

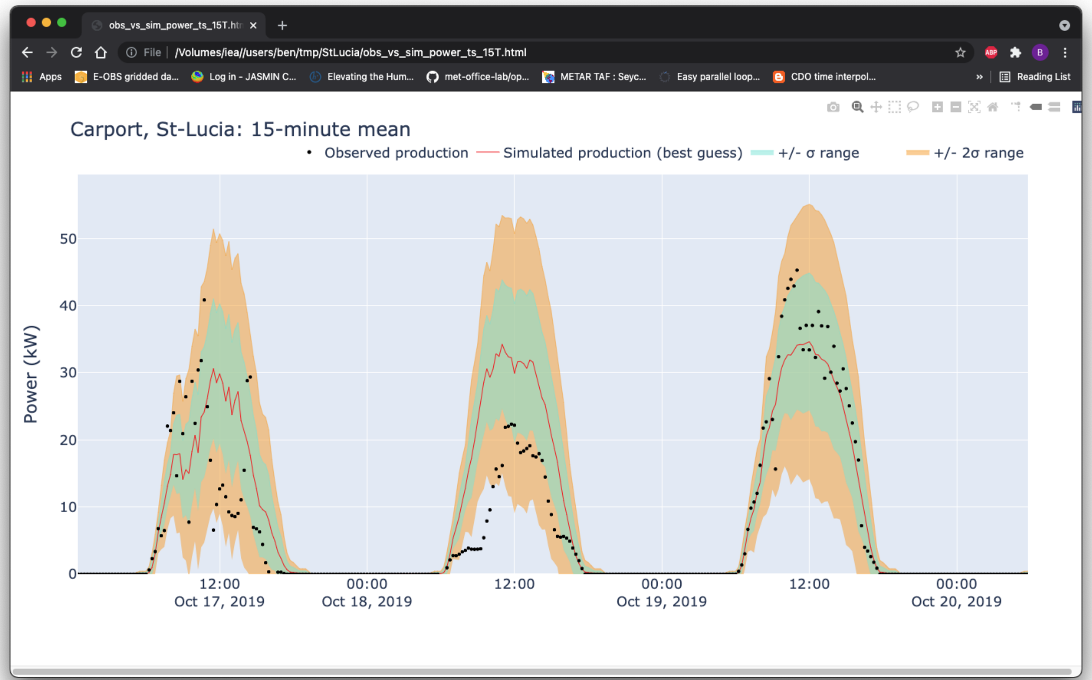


Figure 16: : RE-SAT performance compared with observed production for the Ministry of Infrastructure carport 54kW array. The black dots represent the overserved power produced, the red line is the simulated production by RE-SAT, the colour bands are a representation of the uncertainty (1 sigma or 2 sigma).

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 16 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 17 summarises the simulation errors for the Carport 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.

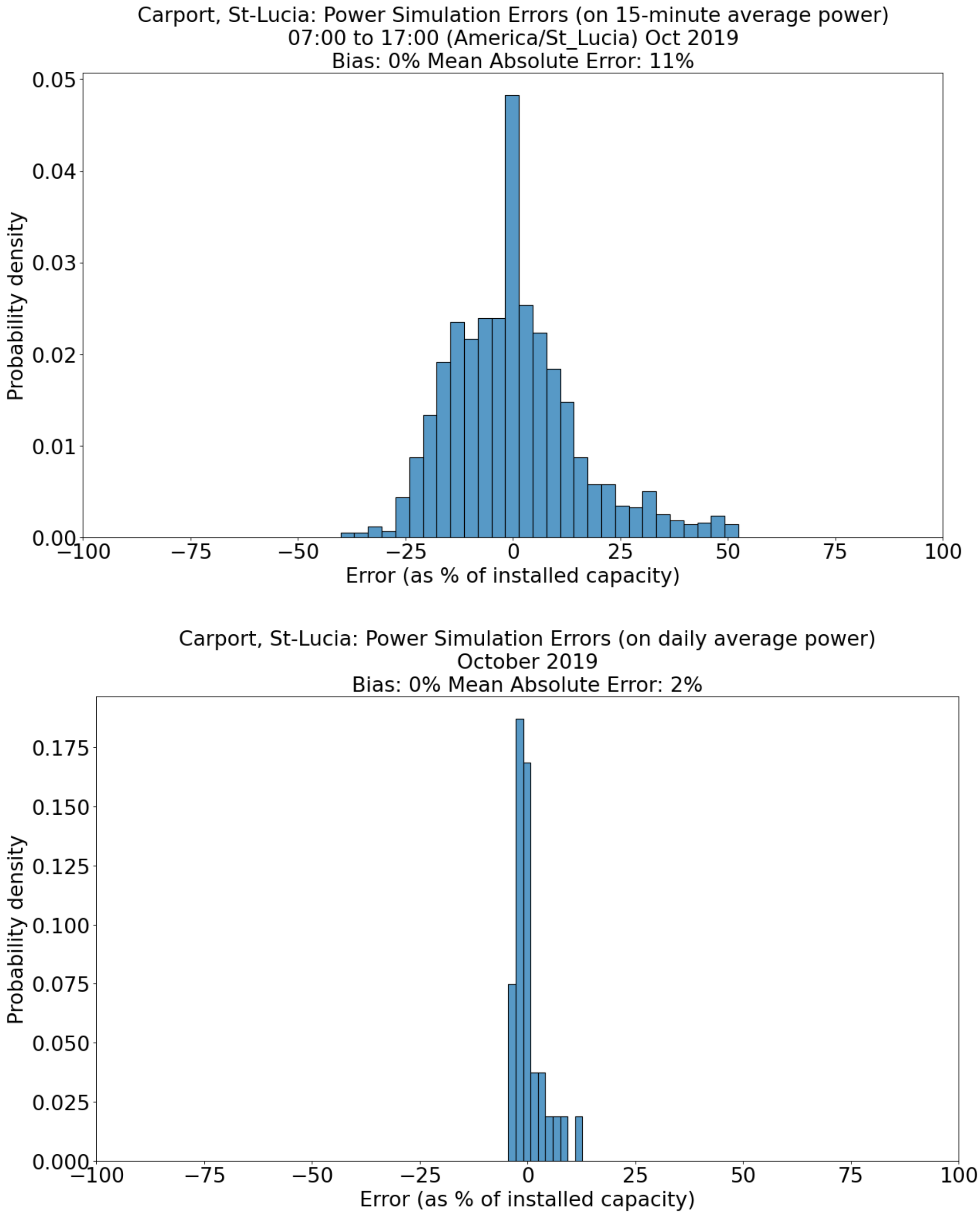


Figure 17*: Histogram of RE-SAT simulation errors for the* for the 54kW solar installation at the Ministry of Infrastructure carport *as measured on the 15-minute average power (upper panel) and the average daily power (lower panel).*

4.5.2. Uncertainty calibration

The orange and green bands shown in Figure 16 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 16) to fall outside of the uncertainty bands.

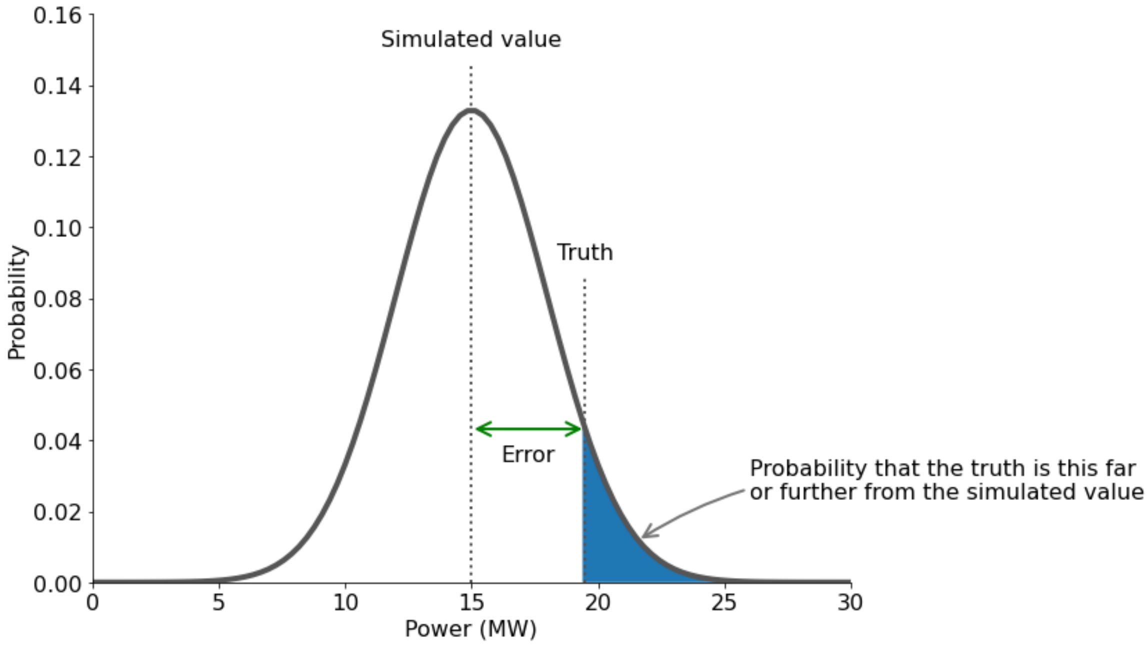


***Figure 18**: Normal distribution of the simulation errors.*

Under the assumption that the simulation errors follow a normal distribution (as shown in Figure 18) 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 19.

The distribution of the simulation errors is shown in the histograms of Figure 17. 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 16) were computed. Reality was inside of the one-sigma approximately 71% of the time. Reality was inside of the two-sigma approximately 92% 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 narrow.

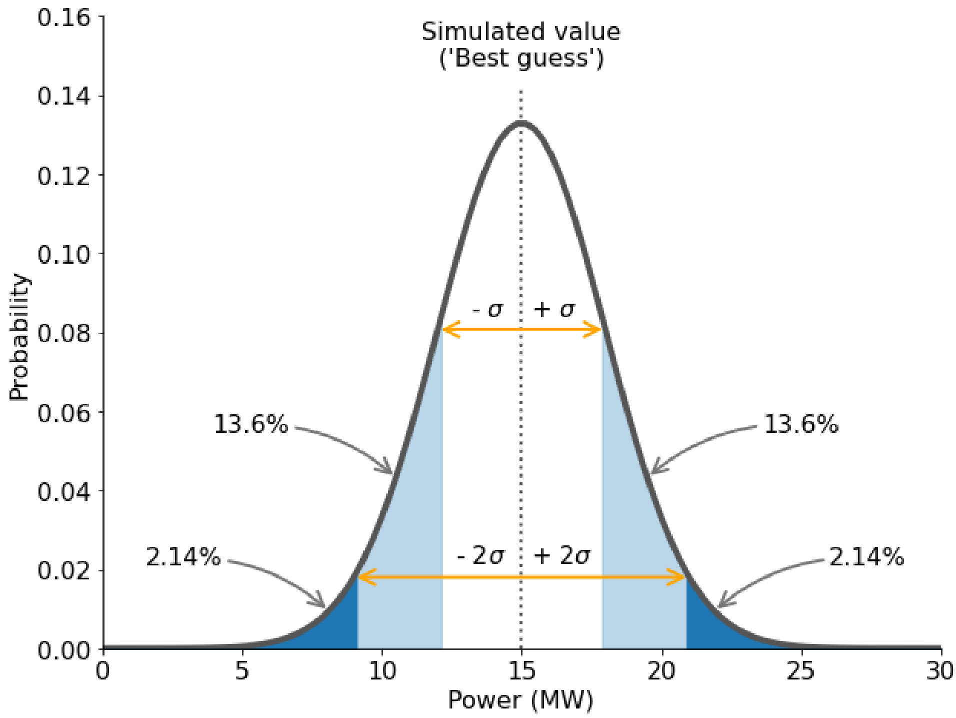


Figure 19*: Probabilistic interpretation of sigma-bands under the assumptions of normally distributed errors.*

In summary:

- Results typically within: 11% for any given 15-minute average, 2 % for any given daily average.
- Negligible bias.
- Uncertainty bands are a little too narrow. Possibly due to sampling error (only one month of useable validation data). The bands could be widened by calibrating against local production data, but additional production data would be required.
- Errors should improve when we begin blending GOES-East weather satellite observations into the simulated weather data.

4.6. Launch of RE-SAT in Saint Lucia

The RE-SAT platform was launched in Saint Lucia during a virtual two-day Training Workshop (5 – 6 July 2021), where the IEA team trained participants on the use of RE-SAT and developed some real energy scenarios with them. A session to discuss the way forward of how the platform would be made available to Saint Lucia after the funded project ends was also included.

> *"Having a tool such as RE-SAT definitely adds value, even if we have not yet implemented it, it has already opened our eyes to possibilities. Even if it hasn't had that much of an impact as it relates to a project running that we utilised it from the get-go. It puts us a frame of mind as to what we can look forward to, even for our ongoing projects, so for me it has already made some level of impact even if we haven't used it in an official sense."* Fabian Lewis, Public Utilities Officer (MIPEL)

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.

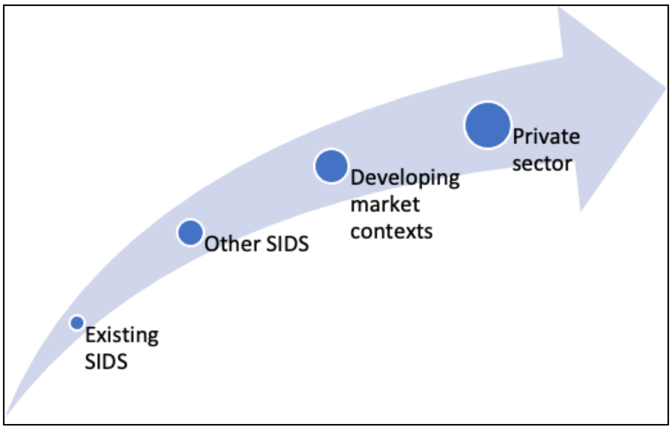


Figure 20: *RE-SAT commercial trajectory plans.*

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 • Balance supply and demand • Minimise costs	• Plan for generation expansion • 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 • Develop sustainable energy infrastructure	• Justify site selection • 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 Saint Lucia to contribute to their transition from fossil fuel electricity to renewables. The Renewable Energy target in Saint Lucia is 35% by 2025 and 50% by 2030. This target is based on a mix of geothermal, wind and solar.

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.

> *"That constant engagement is key. Your constant engagement with us gave us that success."* Kurt Inglis, Public Utilities Officer (MIPEL)
>
> *"The project met its objectives; we have a working platform!"* Shurman Francis, Energy Officer (MIPEL)

PARTNERSHIP ARRANGEMENTS: The Working Group have been effective in ensuring relevant stakeholders are consulted. Although the engagement with the public utilities was not successful, stakeholders in Saint Lucia realised the need for inter-agency cooperation for the success of projects like this as a valuable lesson for the future.

"I think what we need to do better is we need to have an overall better engagement with our stakeholders for things like this, it is important. So that capacity… is not just built in the Ministry, but you have trained stakeholders who understand the things that we do and understand the tools that we use. This is going to be one of the things that we do. It would have been good for them to have stayed on for them to have learned about it and be able to use it to the extent that we are able to now." Kurt Inglis, Public Utilities Officer (MIPEL)

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

"Persistence from your team, you always went back to the drawing board to ensure that our concerns were addressed." Shurman Francis, Energy Officer (MIPEL)

"I think you did a good job! I have not seen any major challenges you couldn't overcome… you have developed the platform and always tried to find the needs. If people are not responsive and you cannot get the input you cannot progress. From your side everything was good." Martin Rufenach, Programme Specialist (OECS)

Relevance

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

"This platform will definitely be very useful as we go forward in terms of planning and looking at certain projects that we are looking at, and how it will impact on our projected targets, and paving the way forward for our electricity distribution stabilisation for Saint Lucia. I feel that the platform will definitely be a plus and can be one of the tools in our toolkit going forwards for Saint Lucia." Fabian Lewis, Public Utilities Officer (MIPEL)

ALIGNED: RE-SAT is aligned with Saint Lucia Government strategies.

"Being able to model the things that we want to implement is very useful to us, because we have a lot of planned projects, we need to know exactly what the impact of those is. This gives us the opportunity to do some modelling before we finalise our planned mitigations to achieve our renewable targets. To see whether or not the things that we have set out in those various documents are actually feasible."" Kurt Inglis, Public Utilities Officer (MIPEL)

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

"The continued engagement and training from your team has definitely been one of the key factors. You have the training documents, collaboration and workshops for capacity building." Kurt Inglis, Public Utilities Officer (MIPEL)

6.2. Impact evaluation

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

The new targets for electricity generation in Saint Lucia are to achieve 35% renewable by 2025 and 50% by 2030 based on a mix of geothermal, wind and solar energy sources. In 2016 a National Energy Transition Strategy and Integrated Resource Plan (NETS)[7] was developed by Saint Lucia Electricity Services Limited (LUCELEC) and the Government of Saint Lucia. This strategy suggested that a combination of solar, wind and diesel together with energy storage might be the best combination for Saint Lucia and might achieve approximately 40% renewable energy penetration. Since then, geothermal resource has been included within the mix and the country has performed a feasibility study for the potential for geothermal power around the Soufriere. The World Bank has also now approved funding for geothermal energy exploration in Saint Lucia (July 2021).

The current status regarding renewable energy in Saint Lucia is the following (2021):

- Solar (exiting installations):
    - 3 MW solar farm in the South of the Island (Vieux Fort)
    - Estimated 1.3 MW of de-centralized installed systems around the island
    - 54 kW Solar Carport at Union installed
    - 200 kW at OKEU Hospital installed

- Wind - Resource assessment carried out in the Dennery area on the East coast. Plans for 12MW of onshore wind (some delays encountered)

- Geothermal - aspiration for a 30MW plant
    - Surface exploration activities: LIDAR survey, Geoscientific studies, Environmental and Social Impact Assessment report, pre-feasibility study
    - Exploratory drilling to follow
    - Funding support from: World Bank India, DFID, Climate Investment Fund (CTF) and SIDSDOCK

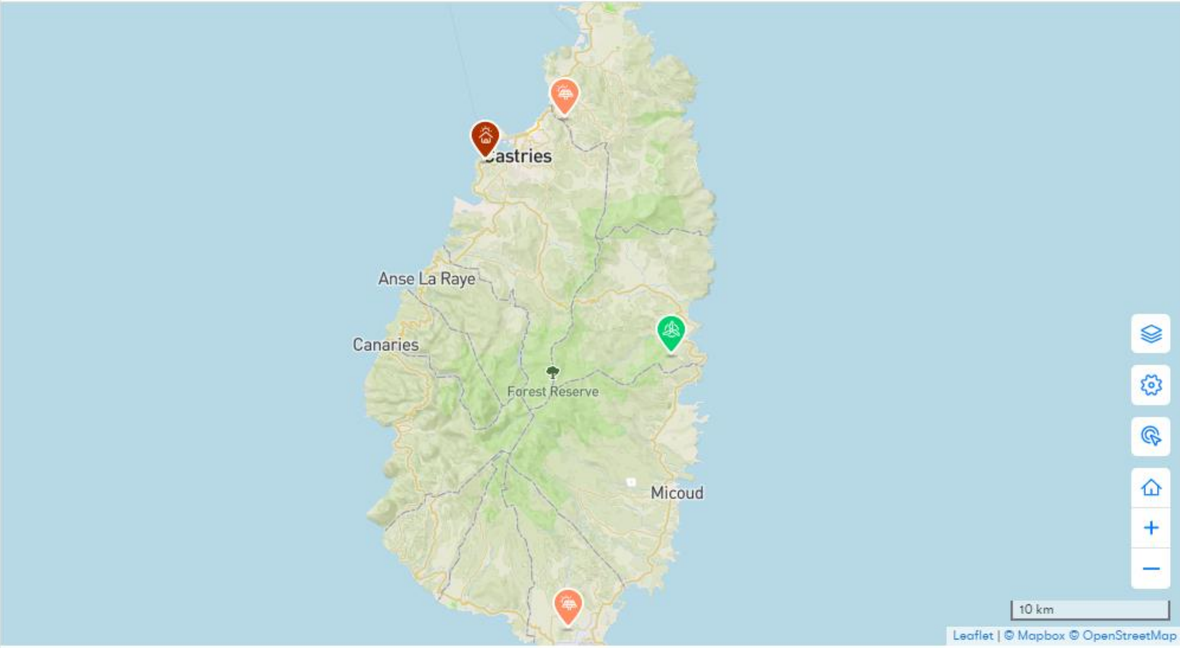
To aid in planning the development of the renewable energy sector, Saint Lucia has used RE-SAT for some specific applications to test the performance of different combination of renewable energy installations. The IEA provided virtual training sessions, assistance by video conference and practical workshops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

[7] Saint Lucia National Energy Transition Strategy and Integrated Resource Plan. http://www.govt.lc/media.govt.lc/www/resources/publications/saint-lucia-nets-executive-summary-final.pdf

6.2.1. Exploring future renewable scenarios with RE-SAT (wind and solar)

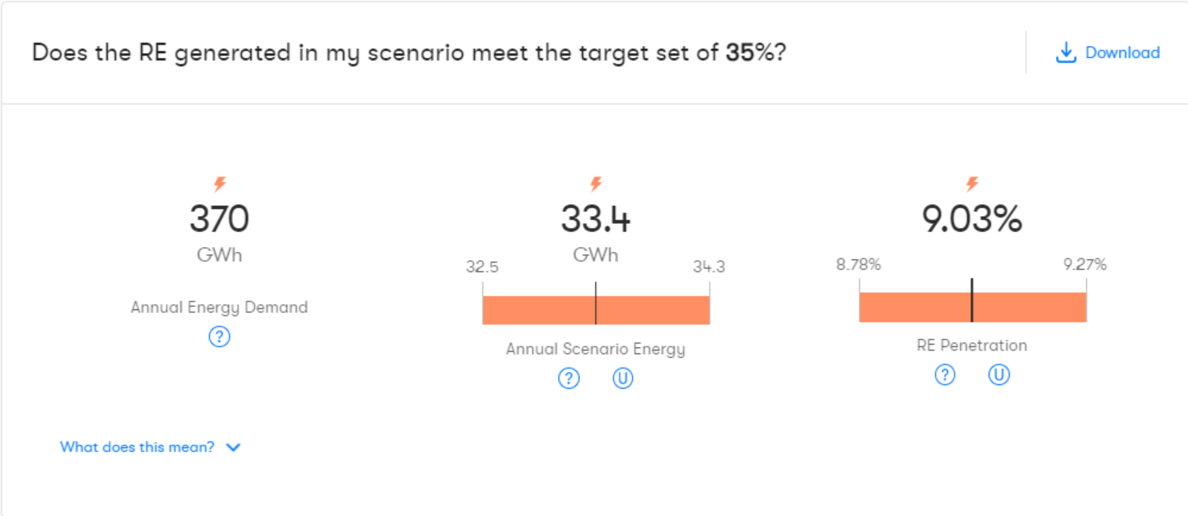
RE-SAT was used to create a scenario for 2025 adding the planned wind farm (12MW) and a new utility solar (10MW) to the existing the existing solar installations (3MW utility solar, 200kW at the Hospital (OKEU) and the 54kW at the Carport in Castries).

Map



Installation type / Unit	Installation year	Tags	AC Capacity kW	Capex per capacity USD per kW	Find on map
Rooftop solar			**200**		
OKEU 200kW	2019		200	3,060	
Utility solar			**13,100**		
Vieux Fort (Assume 0.11 USD nominal tariff)	2018		3,000	2,280	
Carport	2019		54	1,980	
Trumase 10MW	2022		10,000	1,720	
Wind			**12,800**		
Dennery 12MW	2025		12,800	2,060	

The mix of generation in this scenario achieved 9% renewable penetration, assuming an annual demand of 370 GWH for 2025. To achieve the target of 35% by 2025, Saint Lucia would need to explore further scenarios with a mix of solar, wind and geothermal. This was explored in the next scenario.



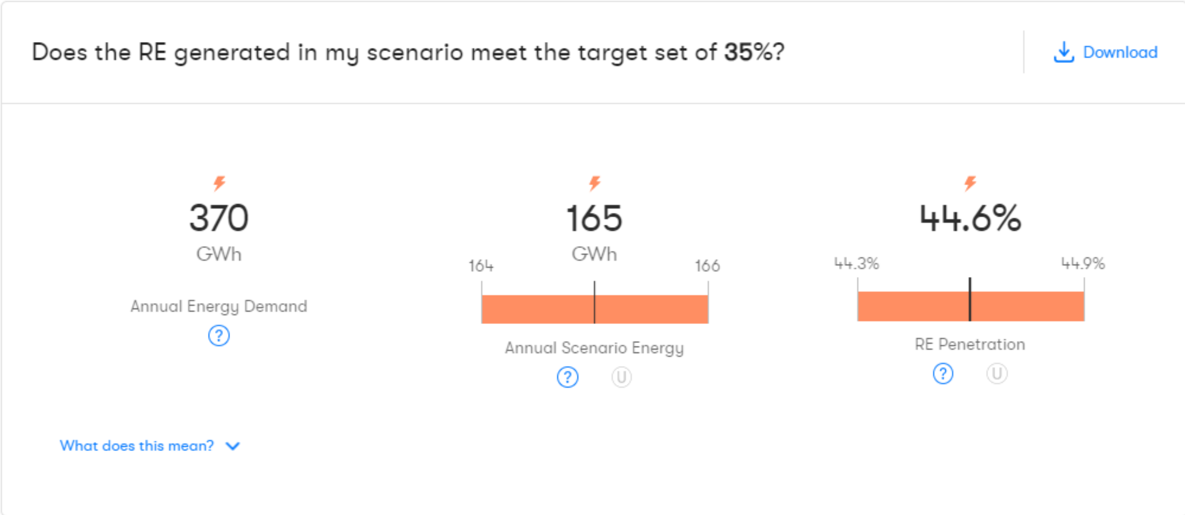
"When you look at the platform, I feel that almost every project we are looking at, we may be able to use the platform in one way or another. I see various potentials and opportunities for it to be utilised, and there are probably some that I have not yet in my mind's eye seen yet. I see lots of potential in it, it can be used with other projects." Fabian Lewis, Public Utilities Officer (MIPEL)

"This platform will definitely be very useful as we go forward in terms of planning and looking at certain projects that we are looking at, and how it will impact on our projected targets, and paving the way forward for our electricity distribution stabilisation for Saint Lucia. I feel that the platform will definitely a plus and can be one of the tools in our toolkit going forwards for Saint Lucia." Fabian Lewis, Public Utilities Officer (MIPEL)

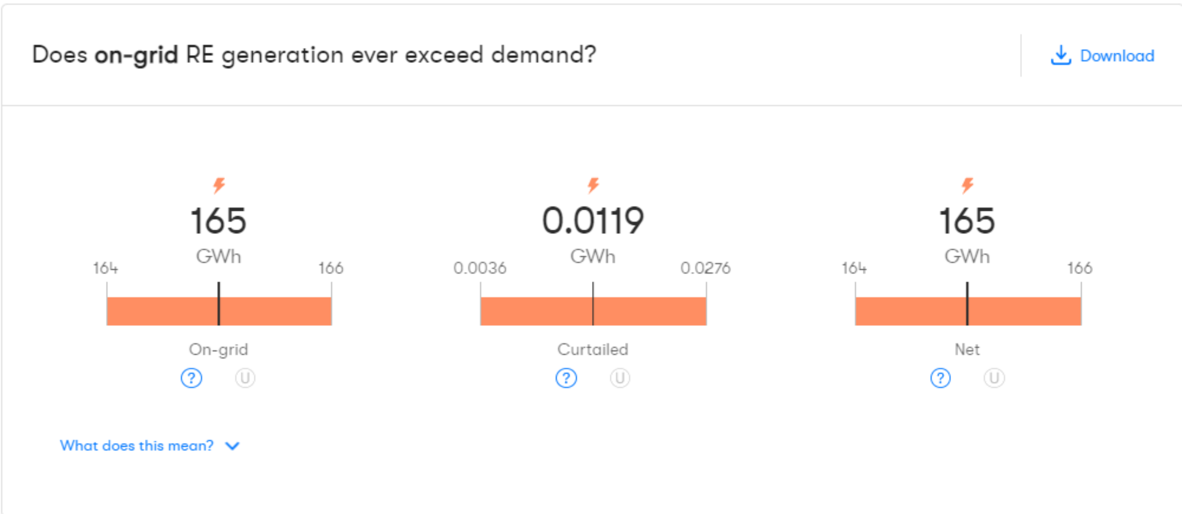
6.2.2. Exploring future renewable scenarios with RE-SAT (wind, solar and geothermal)

Adding the contribution of a geothermal installation of 15MW to the scenario explored above for 2025 achieved a renewable penetration of 44.6%, this scenario surpasses the target, which was a very welcome news for Saint Lucia. The grant financing that Saint Lucia has received from the World Bank will assess the viability of its geothermal resources for power generation. The project will support exploratory drilling, capacity building, technical assistance, and market engagement.

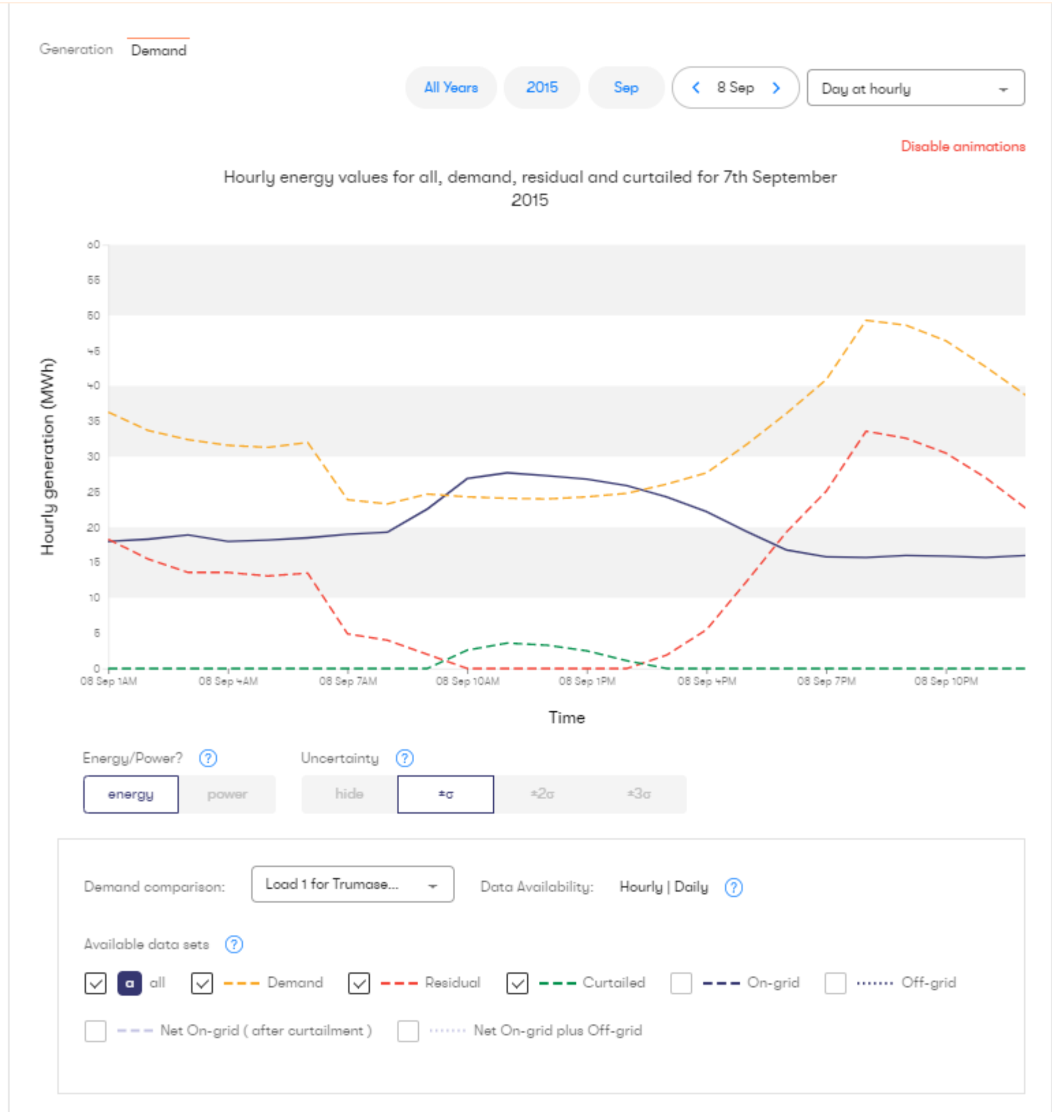
Because of this, the contribution of geothermal power can be added to RE-SAT by treating it as an installation with a fixed output or predetermined time-series of values provided by the user. Together with geothermal, hydropower and biofuel are the other two renewable energy sources that the platform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



This scenario exposed that there could be curtailment of power at times due to the generation exceeding demand.



To explore when curtailment was occurring, a closer look at the data through the Explorer function in RE-SAT revealed that for same days during the middle of the day, the generation (blue line) exceeded the demand (orange line).



Summary

These exercises were the initial attempt to model potential future scenarios to reach the target of 35% renewables by 2025. 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 Saint Lucia officials to assess different scenarios for potential renewable installations, especially the realisation that by adding the 15MW geothermal plant in combination with the exiting installations and a new solar and wind farm, the target of 35% RE by 2025 was not only achievable, but surpassed.

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

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 Saint Lucia are also included.

In-country challenges:

- Timing and relevance are important for co-production: The RE-SAT project was well received by Saint Lucia due to their ambitions to transition to renewables as they saw an opportunity to exploit the platform to their advantage. (Saint Lucia Energy Strategy).
- In-country commitment is vital for the success of partnership projects: The lead partner in Saint Lucia, the Ministry of Infrastructure, Ports and Energy facilitated the engagement with other organisations. The absent of the utilities company in Saint Lucia had an impact.
- There is a lot of competition for workshop time in the recipient SIDS: Many nations and suppliers are operating in Saint Lucia, 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 production data shared by the ministry were very important for the validation and calibration of the tailored RE-SAT application in Saint Lucia.
- Local capacity to receive knowledge transfer varies across countries and therefore delivery methods need to adjust accordingly. For some of the organisations involved in Saint Lucia, 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 Saint Lucia was welcome and crucial for the co-development of the platform that is fit-for-purpose.
- Continuous engagement and following up with partners were welcome. Continuous communication has been essential for the co-development of the platform.
- Capacity building was challenging during the pandemic and has limited the delivery of value. In Saint Lucia, the pandemic, together with a change of lead stakeholder within the project, had a special impact, as we only managed to hold 1 face to face visit (the Discovery visit in 2018). The rest of our visits were held on online. Although these virtual workshops were successful in conveying the key messages, 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. Saint Lucia were featured in 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.
- 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 the application 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. Geothermal is also important for Saint Lucia and they benefitted from this additional generation capacity.
- 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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