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Clean energy for EU islands: Smart Electricity Systems, BES islands, Netherlands

Clean energy for EU islands

Smart Electricity Systems:

Scalability of the planned smart infrastructure to integrate distributed RES and smart grid technology

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Introduction

The Dutch Caribbean islands of Bonaire, St. Eustatius and Saba (BES islands) have been selected as one of 30 islands/island groups that hold a vision of achieving 100% renewable energy by 2030. In order to achieve such an ambitious goal, the BES islands are developing many activities in the electricity sector. In the period 2024 – 2026, the Clean energy for EU islands (CE4EUI) secretariat will be working together with the BES islands to support activities related to smart electricity systems, electrification of mobility, and integration of decentralised renewable energy.

The main focus of this report is on mapping the planning and further implementation of the advanced electricity metering infrastructure on the BES islands, which is the basis for the implementation of the smart electricity system. This report represents the result of the first support activity focusing on smart electricity systems and will be followed by a roadmap for the implementation of optimal solutions.

While all Dutch Caribbean islands have started the process of planning and implementing advanced metering infrastructure (AMI) for both the electricity and water systems, they are all at different stages. While the report focuses on the BES islands, it also gives a brief overview of the situation on the rest of the Dutch Caribbean islands: Curaçao, Aruba, and Sint Maarten. The report is based on the research and interviews conducted with each of the utility companies of the Dutch Caribbean islands. Although the target audience is the team of stakeholders from Bonaire, Saba and St. Eustatius, including governments and utility companies of these islands, the authors have also had interviews with representatives of the utility companies of Sint Maarten (GEBE), Curaçao (Aqualectra) and Aruba (WEB Aruba and Elmar).

This report is split into four parts. The first part provides an overview of the current situation of advanced metering infrastructure planning and implementation on all Dutch Caribbean islands, including the overview of electricity, water, and street lighting infrastructure. The second part reviews the existing business cases for the implementation of AMI, specifically in St. Eustatius and Saba. The third part provides best practices for the use of AMI from other countries. Finally, the last part includes an outlook and recommendations for the next steps for the BES islands.

Current status of smart electricity systems in the Caribbean islands

The secure and reliable electricity supply of non-interconnected island systems requires well-balanced production and demand. For sustainable long-term development, islands are aiming to use locally available and carbon-free energy sources, solar and wind being the key sources considered by most. However, solar and wind power plants yield variable electricity supply, which requires flexibility from the rest of the electricity system to ensure reliability. Additionally, to efficiently balance and control such electricity systems with distributed generation and to decrease losses in the system, the implementation of smart grid technologies is necessary. The prerequisite to smart grids is the installation of advanced metering infrastructure (AMI). This report focuses on the current status, planning, potential and future steps for the implementation of AMI on the islands of Bonaire, St. Eustatius and Saba (BES islands).

The BES islands have vertically integrated electricity companies, which are, in most cases, also utilities responsible for water and street lighting on the islands. Additionally, independent electricity producers are allowed to participate in the electricity system. This chapter gives an overview of the current status of the AMI for electricity, water, and street lighting infrastructure on the BES islands, as well as on Aruba, Curaçao, and Sint Maarten, thus giving a complete picture of the implementation of AMI on all Dutch Caribbean islands.

The utilities of Curaçao, Bonaire, Saba, and St. Eustatius signed a Memorandum of Understanding (MoU) in February 2023 in Curaçao with the aim to join forces in optimising operation of utilities, including their energy sectors[1]. The goal is to organise regular meetings between utilities to exchange experiences, share knowledge and align actions for optimal implementation. In addition, in May 2023, the Netherlands signed a Memorandum of Understanding with Aruba and a Memorandum of Understanding with Sint Maarten.[2] These collaborations focus on various renewable energy technologies and establish an agreement on the exchange of personnel and scientific and technological knowledge and the organisation of joint working groups and research projects.organisation of joint working groups and research projects.

Saba

Saba has an annual electricity demand of 9.2 GWh.[3] Of this, up to 40% of the electricity currently comes from renewable energy generation, namely two PV power plants and a centralised battery energy storage system[4]. Saba is located in the area of the Caribbean that is exposed to hurricanes.

Saba's government adopted Saba's Energy Sector Strategy in 2019 with the aim to identify key pillars for action and targets in order to reach its long-term vision of becoming a 100% sustainable energy island. This Energy Strategy is valid for the period 2020-2025 and establishes a target of 60% energy sector sustainability by 2025. To achieve this target, the Energy Strategy identifies four main actions:

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[1] Memorandum of Understanding between Curacao, Bonaire, Saba and St. Eustatius utilities signed in February 2023 (Link) The MoU focuses on the broad spectrum in which the utility companies operate in, including but not limited to security, drinking water, electricity, renewable energy and smart-grids.

[2] Two Memorandum of Understanding between the Netherlands and Aruba and the Netherlands and Sint Maarten (Link)

[3] Dutch government report prepared by TNO in 2022 titled “Energy transition of Bonaire, St. Eustatius and Saba”

[4] Saba electric website (Link)

- Increase in efficiency of energy use. Key actions include the implementation of energy-efficient lighting infrastructure and the use of solar thermal for water heating.
- Increase in renewable generation.
- **Update the current electricity grid and improve flexibility to be able to integrate more renewable energy and ensure the reliability of the system. Actions include the implementation of smart grid and use of storage.**
- Continue the analysis of the use of geothermal energy in collaboration with neighbouring islands.

In January 2022, the Dutch government published a TNO-prepared study on the energy transition of the BES islands. It recommended the implementation of a large-scale wind power plant to reach 80% renewable energy penetration on the islands. Additionally, in 2022, Saba Electric adopted the renewable energy road map and action plan, which outlines Saba's plan for reaching the 100% renewable energy target by 2030. This plan defines that the hybrid power plant comprising 0.5 MW wind, 6 MW PV and 15 MW Battery Energy Storage System (BESS) will be used to achieve an 89.1% share of RE in electricity. The implementation of this project is financed by the Dutch national government and an EU multiannual indicative programme and is expected to be realised by the end of 2025. This ambitious plan has already started with implementation.

Saba Electric (SEC) is the vertically integrated utility responsible for the island's electricity and public lighting infrastructure. The water metering infrastructure is instead managed by the local Saba government – the Public Entity of Saba. SEC is responsible for the infrastructure, which includes:

- 1,380 electricity end-users. Of these, 300 are equipped with digital electricity meters, while 1,080 are equipped with an analogue meter (Landis+Gyr). Current digital meters are read with a handheld Itron device and cannot be monitored or controlled remotely. The collected readings from digital meters can be uploaded to the Itron system for billing purposes.
- 391 streetlights. LED streetlights have been installed, and there is an option, which is not currently used, to add a smart photocell for remote control of the lights.

Further plans of SEC are to carry out a detailed techno-economic analysis and develop a business case for the implementation of AMI. Considering existing good collaborations with St. Eustatius utility STUCO, SEC is looking into joining forces and ensuring easier and potentially more economical implementation of electricity AMI.

St. Eustatius

St. Eustatius (Statia) island has an annual electricity demand of 17.3 GWh. In 2024, the share of electricity coming from renewables increased from 38% to 55% with the installation of additional solar power (PV) and BESS hybrid power plants. Renewable electricity on Statia comes from three hybrid plants, each including PV + BESS, which ensure the reliability and flexibility of the system. Statia, like Saba, is located in the area of the Caribbean that is exposed to hurricanes.

In the above-mentioned TNO study published in January 2022, possible scenarios are analysed to decarbonise Statia. The next steps suggest the installation of a hybrid power plant with wind, PV and storage. To ensure flexibility of the electricity system, the study also proposes increasing the number of water tanks since increasing the water storage capacity at the reverse osmosis desalination plant can be used as a flexible demand option as well. The ongoing energy transition in Statia should ensure the implementation of the smart grid to allow better monitoring and management of the grid. The initial step in this process is the implementation of AMI.

Statia utility company, STUCO, is responsible for electricity, street lighting and water infrastructure. When it comes to metering infrastructure, STUCO currently has:

- 1,950 electricity meters – 75% of these are digital and 25% analogue meters and can only be read manually (for digital devices using a digital handheld device).
- 1,150 drinking water meters – all of which are analogue. In collaboration with Aquaelectra, eight district analogue water meters have been replaced by digital Itron Flodis[5] meters. These mete[6]Itron Temetra software⍰[7]radiofrequency (RF) based meter read-out. and require a drive-by for radiofrequency (RF) based meter read-out.
- Currently, the data from these digital meters is uploaded to Temetra software used by Curaçao's utility, Aqualectra.
- Installation of only district-level digital meters already results in effective monitoring and provides a tool for STUCO to execute a targeted and more efficient means of finding water leaks; the aim is to reduce the non-revenue water from as high as 40% in 2023 to 20% by year-end 2024 with a continued reduction planned for 2025.
- All 550 streetlights have LED lighting. However, there are currently no options for remote control or programming of lighting (smart street lighting). This is planned, but electricity and water metering infrastructure are a priority due to non-technical losses and the changes in the electricity system.

STUCO is already in the process of planning the implementation of electricity and water AMI. This will follow the example of AMI implementation in Curaçao, which will be further discussed under the SES business case analysis in the next chapter.

Bonaire

The island of Bonaire has an annual electricity demand of 126 GWh, with a rapidly increasing population. The share of electricity coming from renewables is approximately 25% of the overall generation. Renewable electricity is obtained from a hybrid plant, including 11 MW of wind, 6 MW of PV, and 14 MW/14 MWh BESS system, and approximately 2 MW of registered distributed rooftop PV across the island. Bonaire is located in the area of the Caribbean that is less exposed to hurricanes.

Since 2020, a plan has been developed with stakeholders to achieve an optimal mix of energy generation, reaching up to 80% sustainable energy (the hybrid plan 1). After the completion of the first part, the hybrid plan two is now being developed:

This hybrid plan 2 includes:

- Increasing solar PV capacity by 9 MWp;
- Boosting the capacity of high-speed generators (for peak shaving) by 14 MW, with a phased deployment by 2030 as peak demand grows;
- Enhancing the capacity of medium-speed generators (for base load) by 14 MW in two phases: an immediate addition of 8 MW, followed by 6 MW in 2028;
- Increase wind energy capacity by roughly 35-36 MW through three phases:

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[5] Itron Flodis digital district water meters (Link)

[7] Itron Temetra software currently used by Curacao's Aqualectra and Statia's STUCO (Link)

- Upgrading the Morotin wind park from 11 MW to 24 MW;
- New capacity wind energy of 11-12 MW at a new site (e.g., Washikemba) as soon as feasible;
- New capacity of 11-12 MW at the same site in 2030;
- Expanding the Battery Storage System (BESS) capacity by at least 2 MW/2 MWh by 2030, with the size and timing to be further assessed based on grid stability analyses.

WEB Bonaire is Bonaire's utility company responsible for electricity, street lighting, drinking water and wastewater systems. When it comes to metering infrastructure, WEB Bonaire currently has:

- 13,000 electricity end-users. A project to replace electricity meters with smart meters of type Landis+Gyr E350[8] has started. Currently commercial customers are equipped with smart meters, and a pilot is operational to test the use with households. [9] has started. Currently commercial customers are equipped with smart meters and a pilot is operational to test the use with households.
- Currently, 1.3% or around 170 end-users have installed smart meters. This represents a proof-of-concept phase for RF 450 network. The current plan is to initiate full implementation in 2025, expecting that it will take three to four years.
- 12,000 water end-users. Smart water meter installation is yet to start, but it is planned to be implemented in parallel to the electricity meter replacement.
- 4000[10] public lighting posts. In 2023, a start was made on replacing conventional public lighting with more energy-efficient LED lighting (LED Roadways Lightning occurring via the Liveable cities platform). This type of lighting is equipped with a module that allows them to be controlled remotely in a smart way. This has created possibilities to dim the light points at certain times or even turn them off or flash them in order to warn in the event of a road closure or traffic accident. Network disruptions can also be detected. This project is funded by the Public Entity of Bonaire (Openbaar Lichaam Bonaire).
- 1,200 connections for the wastewater system.

The installation of electric smart meters has many benefits, and Bonaire is looking to utilise in the first place:

- Remotely faster and simultaneous recording of the meters;
- A better energy balance, which allows, among other things, to better map non-revenue energy;
- A better service to the customers;
- Providing services such as monitoring the quality of the voltage and continuity of supply.

Bonaire's smart electricity system is based on the RF450 network[11] from the smart meters and internet communication using fibre optics from the substations, as explained in the scheme below. While this system is still in the testing phase, it is expected to become the standard solution used

[8] Landis+Gyr E350 smart electricity meter used in Bonaire (Link)

[10] It is expected that the number of lighting posts will increase to 5000 in the coming years.

[11] In partnership with DAEL (Nokia)

in Bonaire. The Netinium platform[12] is used by WEB Bonaire, and it has an annual subscription for the Meter Data Management System. for the Meter Data Management System.

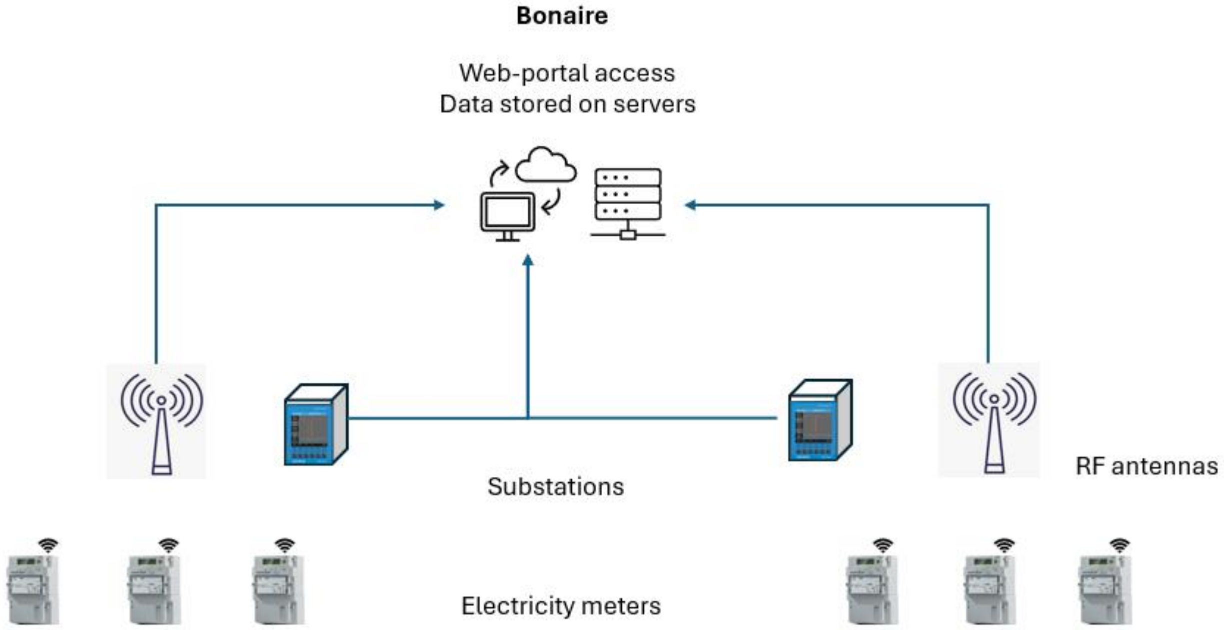

Figure 1: Bonaire's smart electricity system

In 2010, a fibre optic network was installed between the most important power stations for the monitoring and signalling of the electricity network. This covers almost the entire island of Bonaire. Meanwhile, the fibre optic network is also used for monitoring and control of the drinking water and wastewater systems. Additionally, since the fibre optic cable contains multiple fibres, the connections were also used for IT communication at a later stage. The fibre optic network is managed internally by WEB. The policy is that a fibre optic connection will always be included in underground extensions in the future.

The implementation of the Smart Electricity System in Bonaire started with monitoring the substations. Power quality meters (type Janitza UMG96PQ-L)[13] are installed at sub- and distribution stations and can be read from a central location. In addition to contributing to a better energy balance, the information also plays a role in managing assets by monitoring the load capacity of important components in the grid and the quality of the energy supplied. In combination with the expected smart meters, a better energy balance contributes to more efficient monitoring of energy losses (Non-Revenue Energy) so that concrete actions can be taken to reduce this as much as possible.

As part of the Smart Electricity System implementation, WEB Bonaire has funded and launched the implementation of the e-smart registration of assets project. Using high-resolution photos from drones and Artificial Intelligence (AI), the registration of assets is recorded in a database with a high level of detail. In combination with a GIS system, the manageability of assets is greatly improved. Phase two of the project is currently being rolled out, through which the technical status of components is also monitored using AI. This is an important input for a (corrective and preventive)

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[12] Netinium platform for management of smart metering data (Link)

[13] Janitza UMG-96-PQ-L power quality meters are used to measure energy, power quality and residual current monitoring (Link)

maintenance program since potentially failing components can be identified and replaced early. Additionally, a good and dynamic asset registration is important as a foundation for a Smart Electricity System.

Investments in the electricity system required to facilitate growth and sustainability are defined as being very high by the island stakeholders. In order to optimally utilise the high potential for local renewable and sustainable electricity, minimising curtailment, to accommodate the growth of the island and the expected rise of electricity consumption for transport (road, air, or water), the development of a Smart Electricity System is becoming increasingly important and is being further researched. Demand and supply management is seen as a necessary action for the coming years.

Sint Maarten

Sint Maarten's electricity system is fully dependent on fossil fuel generation. The thermal power plant has a capacity of 97 MW.[14] Currently, there are small, distributed rooftop installations. Sint Maarten is located in the area of the Caribbean that is exposed to hurricanes. [15] Currently there are small, distributed rooftop installations. Sint Maarten is located in the area of the Caribbean that is exposed to hurricanes.

The Sint Maarten government adopted a National Energy Policy in 2014.[16] This policy envisioned the decarbonisation of the electricity sector with the target of reaching 80% RE by 2020 and 85% by 2025. Based on the local conditions and available RE generation, solar PV generation was proposed as the main source of RE. Additionally, to achieve this ambitious goal, the policy proposed the use of a waste-to-energy plant and, eventually, offshore wind. This energy policy also placed a strong focus on energy efficiency as well as on the need for upgrades of the electricity grid and implementation of the smart grid. While RE generation goals have not been met, Sint Maarten has started upgrading the electricity grid. A newer or updated energy policy has not been adopted yet. a strong focus on energy efficiency as well as on the need for upgrades of the electricity grid and implementation of the smart grid. While RE generation goals have not been met, Sint Maarten has started the upgrades of the electricity grid. A newer or updated energy policy has not been adopted yet.

Sint Maarten utility company, GEBE, is a vertically integrated electricity company and is responsible for electricity, street lighting and water infrastructure. GEBE has already started the implementation of AMI. When it comes to metering infrastructure, GEBE currently has the following:

- 22,000 electricity connections – of which 10,000 have been replaced with smart electricity meters from Unique[17]. The implementation of the complete AMI system with communication has been completed for 3,000 end-users.
- 22,000 water system connections – of which 3,000 have been replaced with smart water meters from Unique.

[14] Installed capacity has recently (June 2024) decreased by 15 MW due to failure of operation of diesel generators. The issue resulted in a black out and is being restored. (Link)

[16] Sint Maarten National Energy Policy from 2014 (Link)

[17] Unique smart metering solutions (Link)

The implementation of the AMI system is ongoing with smart meters being constantly installed. The scheme of the electricity and water metering AMI system currently being implemented in Sint Maarten is provided in Figure 2 below.

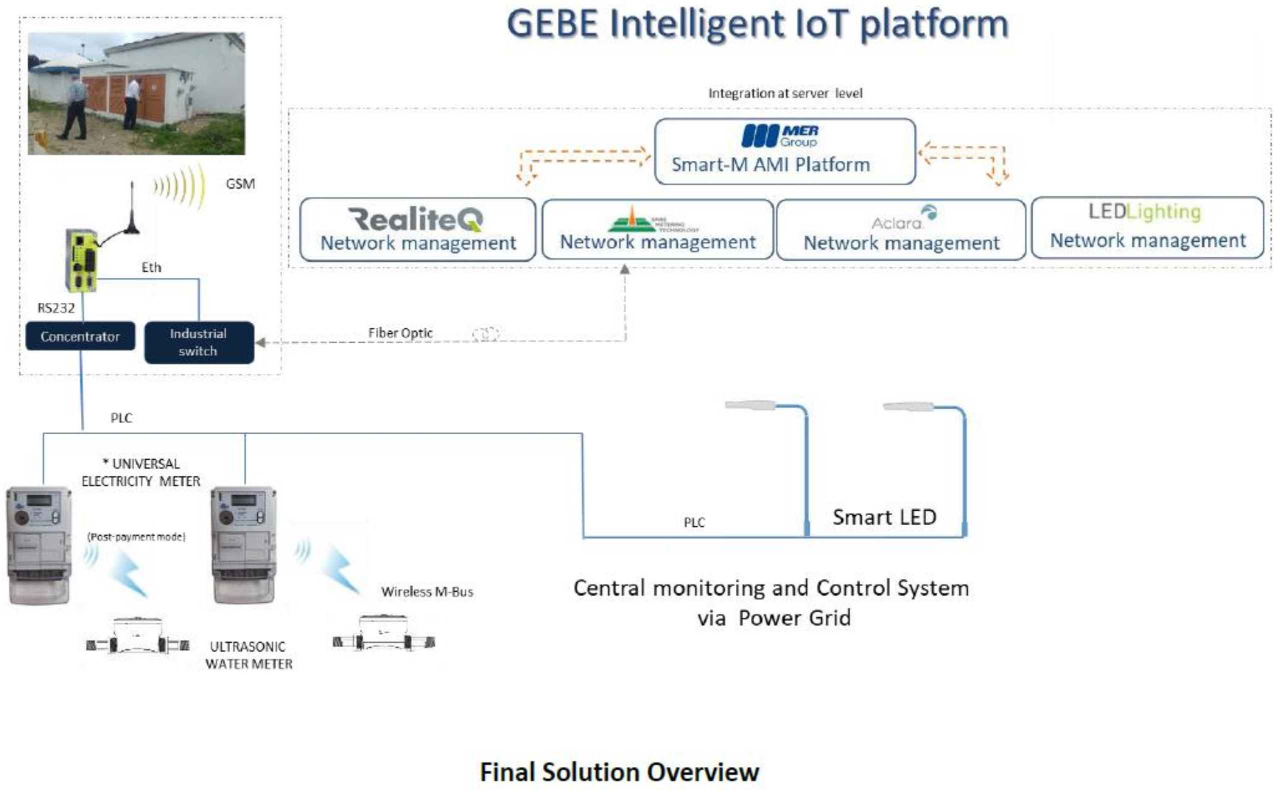

Figure 2: Scheme of the AMI of the electricity, water and street lighting system being implemented in Sint Maarten[18]

Sint Maarten's AMI system connects the electricity, street lighting and water infrastructure. Namely, water meters communicate to an RF device located on the electricity meters using long range (LoRA) communication. Water and electricity data from electricity meters and smart street lighting is transferred using Power Line Communication (PLC) to the concentrator located at the transformer station, which also reads data. From the concentrator, the data is transferred to the central server using fibre optics.

The implementation of AMI system started with three pilot projects testing different ways of communication, including SMS and PLC. Since Sint Maarten is in the hurricane belt, the priority in the AMI decision making is that infrastructure and communication be as protected as possible from interruptions during hurricanes. Hence, the decision was made to use local RF, PLC, and fibre optics, which are located underground.

As GEBE is financing the implementation of AMI, this is being done in phases to spread the costs. Fibre optic installation is the most expensive aspect; hence, while currently, there are many smart meters installed, the complete communication is now in operation for a district with 3,000 connection points.

Lessons learned from previous testing and current use of AMI systems are:

- Frequent alarms as a result of tempering with the meters by customers;

[18] Scheme from MER Group report titled "POC Smart Metering Solution GEBE" from May 2018 – provided by GEBE

- Possible leaked messages for water meters: the next step includes communication with the customer to stop the leak;

Implemented smart electricity meters have many features, including:

- Remote reading and automatic data transfer to billing;
- Semi-automatic connection/disconnection:
- Direct meters that can remotely connect and disconnect are only provided to the strategically important end-users;
- Water meters require manual disconnection;
- The reducing option is programmed into a meter.

Sint Maarten provided pricing for the equipment and services needed for the implementation of the AMI system. The pricing of the metering infrastructure is similar to the equipment prices discussed in the next chapter. In the implementation of AMI, Sint Maarten included a price for external service used on the scale of 100,000 USD, including:

- Integration of MDMS and GEBE admin software;
- Training of GEBE staff;
- Implementation of the system;
- Software portal to be used – single software solution is used for electricity, water, and street lighting data.

Additionally, using communication with its own low voltage network with PLC significantly reduces the price of implementation of the system.

Curaçao

Curaçao island has an annual electricity consumption of 603 GWh. Of the electricity produced on the island, 26.3% comes from RES.[19] Renewable electricity on the island comes from three wind power plants, a PV plant and more than 1,000 registered decentralised rooftop PV installations. Curaçao is located in the part of the Caribbean which does not experience hurricanes. ed rooftop PV installations.[20] Curaçao is located in the part of Caribbean which does not experience hurricanes.

Curaçao aims to reach a share of 70% of electricity from renewable sources by 2027. To reach this challenging goal, the plan is to upgrade existing wind power plants and install additional PV. To ensure grid flexibility, there is a discussion about the use of BESS and the upgrade of the grid infrastructure. Curaçao has already started the implementation of a smart grid by rolling out AMI.

Curaçao's utility, Aqualectra, is a vertically integrated electricity company responsible for electricity, street lighting, and water infrastructure. Aqualectra has the following metering infrastructure:

- 85,000 electricity customers – of which 15% or 12,700 Sensus Aclara smart electricity meters[21] have been installed;
- 85,000 water customers – of which 50% or more than 40,000 Sensus iPERL smart water electricity meters have been installed;

[19] Dutch government report prepare by TNO titled "Energy transition in Aruba, Curacao and Sint Maarten" published in May 2024

[20] While there are still unregistered distributed PV generation.

[21] Aqualectra Informative manual – AMI your smart meter (Link)

- 33,000 streetlights[22]- of which 10,000 have been replaced with SMART fixtures and LED lights.

A simplified scheme of the AMI system implemented in Curaçao is provided in Figure 3 below.

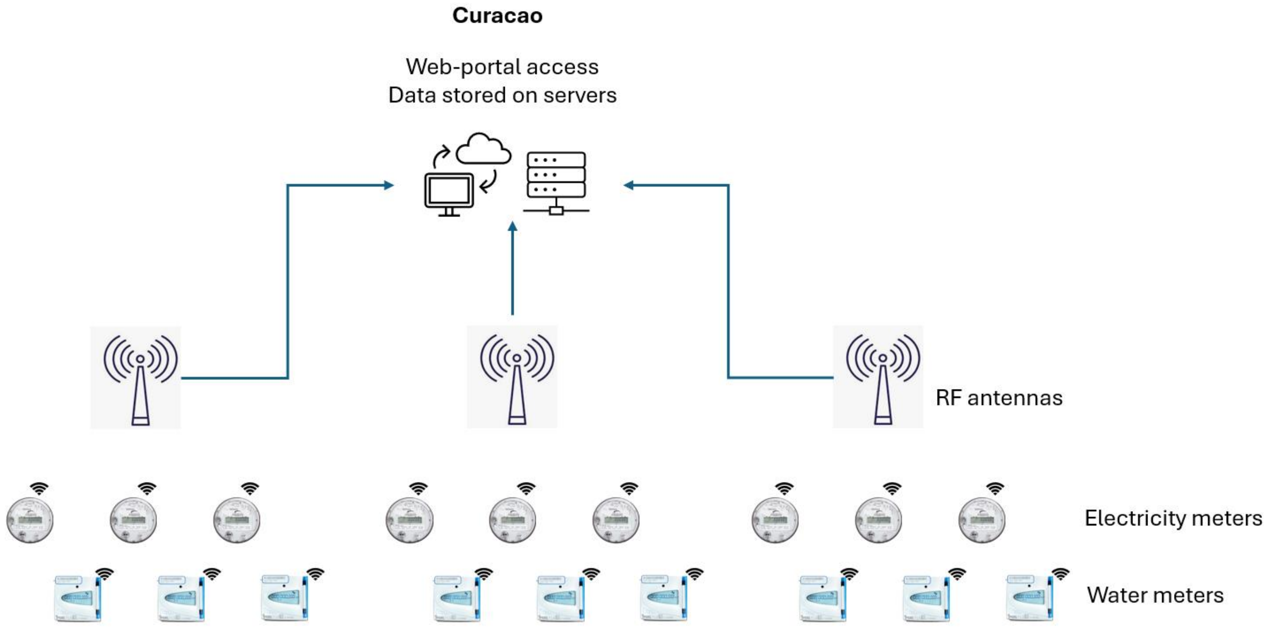

Figure 3: Simplified scheme of the AMI system implemented in Curaçao for electricity and water meters

Aqualectra is investing 200 million dollars over the period of 6-10 years to implement an AMI system and platform. A notable expense aside from development costs is the annual licence fee for the software needed for monitoring and management of the AMI system. While this is a large investment, it has a payback period of only 7 years.

The AMI system implemented in Curaçao uses RF communication from the electricity and water meters to the data collector point at the antenna. From the collector points, the information is transferred to the main servers. For RF communication, Curaçao has installed 16 antennas. Different software are used to manage the electricity system, water system and street lighting system.

The implemented smart electricity meters are mainly being used for the following functionalities:

- Remote reading and direct to billing;
- Remote connect and disconnect;
- Alarm in case of tempering with the meters.

The implementation of the AMI system is already showing significant benefits. For the water system especially, non-revenue costs have decreased from 30% to 1% in the areas where smart water meters were installed. To implement the AMI system, Aqualectra started with the pilot testing in the neighbourhood with 100 customers for a period of one year. These tests showed a significant decrease in non-revenue costs and tempering with the metering devices.

[22] Number of street lights in Curacao (Link)

Aruba

Aruba Island has an annual electricity consumption of 1,060 GWh. Of the electricity produced on the island, 19% comes from renewable sources. Renewable energy in Aruba comes from wind power plants, PV plants, and a large number of distributed rooftop PV plants.[23] To ensure grid flexibility, Aruba currently has a flywheel storage installation and a BESS. Aruba is located in the area of the Caribbean that does not experience hurricanes. Renewable generation on Aruba comes from a wind power plant, a PV plant and a large number of distributed rooftop PV.[24] To ensure grid flexibility Aruba currently has a flywheel storage installation and a BESS. Aruba is located in the area of the Caribbean that does not experience hurricanes.

In 2020, the Aruba government adopted an Energy Strategy plan which included strategic objectives for energy efficiency and diversification of energy generation on the island.[25] Some of these actions were also mentioned in the Master Plan Repositioning our Sails. In 2020, the Minister of Labour, Energy and Integration published its national energy policy[26][27] the main targets set for Aruba are to achieve a 50% share of renewables in electricity generation[28]30 and 90% by 2050. In 2020 the Minister of Labour, Energy and Integration published its national energy policy;[29] the main targets set for Aruba are to achieve 50% share of renewables in the electricity generation by 2030 and 90% by 2050.

To achieve these ambitious targets, Aruba plans to install additional wind, PV, distributed PV, and much-needed energy storage.[30] Aruba has started the implementation of the smart grid through the AMI system. [31] Aruba has started the implementation of the smart grid through the AMI system.

WEB Aruba is the utility responsible for water infrastructure and electricity generation. WEB Aruba has been running a pilot project to operate AMI with the water infrastructure. Due to technical limitations, the pilot was interrupted, and alternative technology is planned to be used in the future to allow for the programming of water meters for the different consumption groups and levels that Aruba has.

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[23] 2100 customers have rooftop PV installation with total of 21 MW

[25] Aruban Government, "Nos Plan, Nos Futuro – National Strategic Plan 2020-2022" (link)

[27] Utilities Aruba, National Energy Policy, (link)
[28] Aruban Government, "Masterplan Reposition our Sails", July 2020, (link)

[30] Dutch government report prepared by TNO titled "Energy transition in Aruba, Curacao and Sint Maarten" published in May 2024

Elmar is the utility responsible for electricity and street lighting infrastructure. Hence, the electricity and water systems are completely separate. Elmar has been implementing AMI in Aruba; its metering infrastructure includes:

- 53,000 customers – of which 80% have had their meters replaced with the Sensus Aclara smart electricity meters. Still, 9,000 customer electricity meters are to be replaced by the end of 2024.
- 11,500 streetlights have been replaced with smart streetlights and use the same system as the electricity meters.

The AMI system in Aruba for electricity system is expected to be completed by the end of 2024. The system, as such is already used by Elmar for monitoring and management of the network. However, once 100% of the meters will have been replaced, Elmar will offer the possibility to end-users to monitor their own consumption with hourly data.

Aruba's AMI system operates using RF communication similarly to that depicted for Curaçao in Figure 3. Aruba's AMI focuses only on electricity meters and street lighting. The Meter Data Management System is managed by Elmar's staff, while annual maintenance is done by a third party.

The main lessons learned and challenges in the transition to the AMI system, based on the implementation in Aruba, have been:

- Need for training of the internal staff to do troubleshooting, analytics with meter data, etc.;
- While meter installation is easy, there is a lot that comes with moving from analogue (paper) to digital system;
- For example, the need for mobile workers to have tablets and be trained;
- For AMI to be installed, more aspects need to be taken into account, such as geolocation needs, communication addresses, etc.;
- An AMI system means that each meter provides 15-minute data. In comparison to before, this results in significant amounts of additional data to manage and analyse. The utility needs to have a clear goal of what it want to manage and get out of the collected data.

SES Business case analysis

The implementation of AMI is the first step towards smart electricity systems (smart grids). The implementation of AMI systems includes two types of costs to be taken into account when assessing a business case:

- Initial costs – which include hardware (meters, endpoint equipment, AMI network equipment, servers, etc.), software (AMI head-end system, Meter Data Management System, End-users portal, training, etc.), and additional services (installation, etc.);
- Operating costs – which include hardware maintenance, software annual costs, support staff costs, etc.

On the other hand, to assess the payback period correctly, it is important to quantify the benefits that come from the implementation of the AMI system. Such benefits include:[32][33]

- Meter reading and re-reads – reduced truck rolls and staff time for manual reads;
- Billing exception handling – reduced staff time for billing exceptions and estimations;
- Customer inquiries – self-service tools to assist customers with near-real-time alerts and improved understanding of consumption;
- Move-in/move-out – the ability to perform remote disconnect and obtain final read;
- Theft identification – near-real-time theft/tamper alerts;
- Outage management – decreased downtime due to near-real-time outage alerts;
- Meter accuracy – replacement of ageing, inaccurate meters;
- Metering service orders – eliminate door tags and physical visits, including non-pay disconnects, and ability to remotely interrogate meters to troubleshoot;
- Asset management – improved efficiency in electric distribution systems, voltage optimisation;
- Capital planning – improved system planning with transformer load analysis;
- Meter replacement budget – offsets any annual meter replacement costs during the business case cycle.

Additionally, social benefits, such as improved quality or security of supply, decrease in power outages, etc., should be addressed whenever possible.

Business cases should provide more than one scenario to clarify the benefits of the chosen implementation plan and its business case. Business cases for St. Eustatius and Saba were analysed, as requested, where St. Eustatius already has an existing business plan prepared, and Saba doesn't.

St Eustatius

STUCO is already in the process of planning the implementation of electricity and water AMI, which will follow the example of the AMI implementation in Curaçao. The scheme of the AMI and communication methods is provided in Figure 4.

[32] IEEE Smart grids (Link)

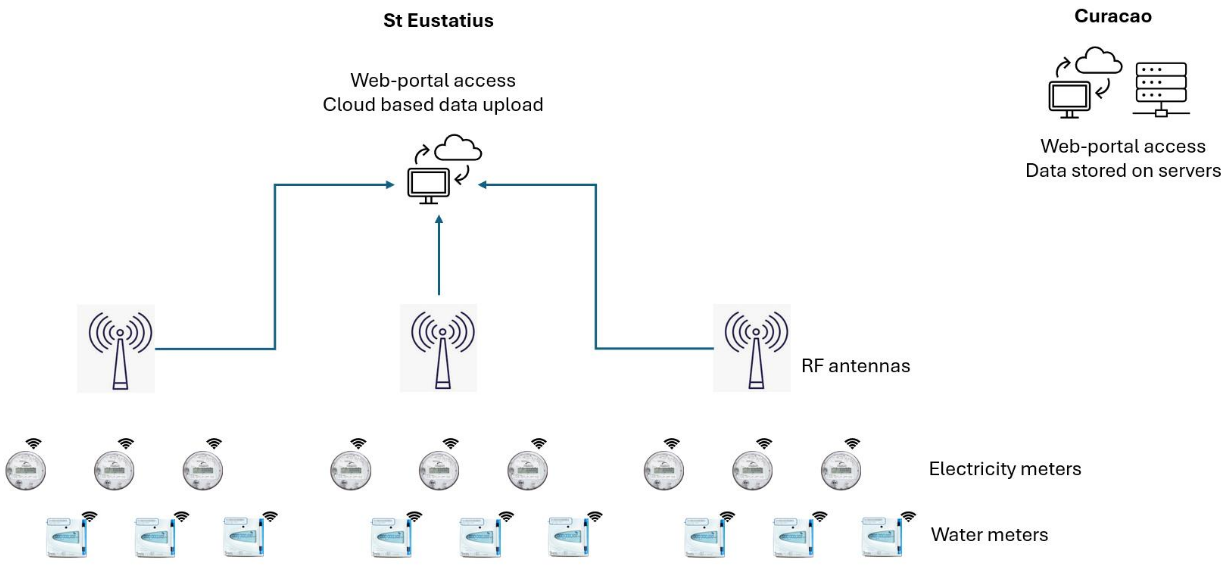

Figure 4: Scheme of planned RF-based AMI for electricity and water systems in Statia

As provided in the scheme, the proposed AMI system in Statia has electricity and water meters communicating using RF to the local base. This is a radial communication system, and there is no communication among the meters. For this system to be implemented, multiple antennas need to be installed across the island. The base collects the data from the meters and uploads the data to the cloud, with servers located in Curaçao. STUCO accesses the data collection and analysis for processing and billing purposes using a web-based application.

Based on this planning, STUCO has already sent a request to the Dutch Authority for Digital Infrastructure (RDI) for the permit to operate their RF communication for AMI at the specific bandwidth. To receive this permit an agreement needs to be reached with neighbouring islands based on an analysis ensuring negligible interference. In addition, STUCO has ordered a business case analysis from a consulting company in collaboration with Aqualectra. The business case with detailed calculations was shared with the authors of this report. The costs of the equipment needed (smart meters, antennas, electronics etc.) are the same if Statia were to decide to implement the system on their own. However, the collaboration with Aqualectra comes into play when discussing the costs of the software licence and usage. Namely, in the proposed implementation and business case, STUCO and Aqualectra are to use the same software licence and share usage costs, as Statia will be included in the system under Curaçao's overall system. Data storage will be in Curaçao, while Statia will have access to the data and software through cloud and web-based applications. Hence, STUCO's staff would still need to be trained for usage of the software, analysis, billing as well as daily maintenance of the overall system.

Taking this into account, the provided business case foresees that the implementation of the overall AMI for electricity and water systems would cost 2.42 million dollars. An overview of the costs is provided in the table below.

TABLE 1. ESTIMATED COSTS FOR AMI IMPLEMENTATION FOR ELECTRICITY AND WATER SYSTEMS IN STATIA, PREPARED BY STUCO AND AQUALECTRA.

#	Description	Amount [$]
1a	Material costs (incl. installation)	1,686,366
	Electricity meters	867,152
	Water meters	341,882
	Communication	278,251
	Hardware	70,085
2	Project external support	349,600
3	Project internal support	54,000
4	External implementation partner	144,220
5	Contingency, unforeseen (10%)	316,818
Total CAPEX		**2,422,007**

Table 1: Overview of costs for deploying AMI

Taking into account the information provided and the fact that Statia is still in the planning stage of implementation of AMI, below a SWOT analysis of the foreseen business case is presented.

Strengths	**Weaknesses**
▪ Using one system to manage electricity, water and smart street lighting. ▪ Collaboration with Aqualectra ensures cheaper implementation due to lower software system costs.	▪ RF antennas' safety needs to be ensured in case of hurricanes. ▪ In case of a power outage in Curaçao, Statia might have challenges to access its data.might have challenges to access its data[34]. ▪ Lack of the second scenario for implementation. Only one implementation plan assessed within the provided documentation.
Opportunities	**Threats**
▪ Collaboration with a utility that already has experience in the implementation and operation of AMI. Additionally, a similar system was applied in Aruba. - Possible joint implementation with Saba could additionally decrease costs for external support and training.	▪ Dependence on Aqualectra for longer-term[35]software use. - Special attention should be placed on data security.

Table 2: SWOT analysis AMI Statia

Assessing different systems that have been implemented in the Dutch Caribbean islands, the proposed system for Statia is similar to the system used in Curaçao and Aruba. However, both of these islands are much bigger and located outside of the hurricane area.

[34] This risk is mitigated with Aqualectra having back-up power for its servers.

[35] This risk is mitigated by potential to use Software-as-a-Service option from Sensus in the future if Aqualectra is to move in another direction.

Saba

Saba currently does not have a business case for the implementation of AMI but is planning to follow the example of Statia. There are multiple benefits of joint implementation of AMI systems on Statia and Saba:

- Savings can be made by jointly ordering the equipment needed.
- The main costs in the implementation come from the costs of external services during implementation. As Statia, Saba utility also currently outsources IT services, hence, there is no internal staff with software expertise that could be trained for back-office support. The proposal to follow the example of Statia and collocate with a larger island system might be the best solution for the Saba system as well.
- STUCO and Saba electric are both short-staffed due to the size of their utilities. Hence, using a similar system could help share staff if needed in crisis situations. Additionally, during the implementation of the AMI system, some staff will have to be focused on this process and will not be available to cover the everyday responsibilities they currently have.

Of course, a detailed techno-economic assessment should be done to quantify both the benefits and the costs of implementation of AMI systems by Saba, jointly with Statia and within a broad implementation process of another larger Caribbean Island.

SES use and best practices

Smart grids are electricity networks that use digital technologies, sensors and software to better match the supply and demand of electricity in real-time while minimising costs and

[36]International Energy Agency[37]

The implementation of AMI is a first and important step towards smart grid implementation and the ability to both manage and exploit the benefits of decentralised, decarbonised and digitised electricity systems needed for the energy transition.

Besides the ones discussed in the Business case chapter, AMI can bring additional benefits to the electricity system in the future. Some of these include:

- Enabling customer monitoring and awareness of own consumption and allowing for more conscious energy use;
- Enabling demand side management and better control of distributed generation;
- Allowing for a better forecast of demand and generation using data collected through AMI;
- Enabling potential use of pricing structures that offer incentives for efficient energy users (e.g. avoiding peak consumption or encouraging consumption at the time of RE generation), which is especially important with increased electrification of transport;
- Allowing better-informed asset and grid planning and management;
- Decreasing customer complaints and improving customer support. Additionally, AMI can provide automatic warnings and information to customers regarding outages or malfunctions and leakage;
- Enabling insights into customer behaviour and effects. The collected data can be used for profiling users to improve balancing and design of services.

A smart electricity system or smart grid consists of multiple systems working together. Aside from AMI, additional systems that [38]:

- **System automation** such as substation automation, distribution automation and control centre systems;
- System automation requires both hardware additions (automated switches, capacitors, remotely controlled connected devices, transformer, wire and cable sensors) to the electricity grid, ICT equipment (data storage, communication security and backup systems) and supporting software systems (geographical information systems, distribution and outage management systems). The implementation of these systems helps optimise substations, operation and management of the grid, provides a visual representation of the system status and improves maintenance. Additionally, the implementation of these systems helps minimise the impact of system disturbances on the customers.

[37] IEA Smart grids overview (Link)

[38] How2Guide for Smart Grids in Distribution Networks, IEA, 2015 (Link)

- **Utility asset management**;
- Asset management requires the implementation of sensors and communication on the assets so that utilities can manage and optimise asset utilisation and maintenance.
- **Distributed energy resources** (DERs), including distributed generation, demand response, energy storage and EVs;
- For distributed energy resources to be active participants in the smart grid, they require power-conditioning equipment, communication and control hardware, and **already installed AMI**. Smart grids increase the system's ability to integrate more distributed renewable resources into the system. Without monitoring, communication and management of distributed generation, they have been reported to create disturbances and congestion to the grid.
- Demand response represents the variation in the customer's load as a response to the signals and requirements from system operators. Demand response can be implemented as follows:
- direct load control - provides utilities with an option to remotely manage a customer's load;
- demand limiting – the customer is provided with the upper limit in the load;
- Price response – customers are provided with different prices for electricity at different periods (time of use pricing, peak pricing, etc.) or different prices for load levels.
- Energy storage and EVs can provide different services to the electricity grid, can be implemented with distributed generation or can be installed behind the meter for local energy management.

Best practice examples

Germany[39]

Starting from 2024, based on Article 14a of the Energy Industry Act, German distribution system operators are allowed to temporarily limit the load but not turn off controllable energy-consuming assets, in the event of overloads. In this sense, controllable energy-consuming assets are defined as tapping points in low-voltage networks that use power to run stationary electrical heating, water heating and/or space heating or space cooling, as well as non-public electric vehicle charging, and energy systems with a nominal connected load of more than 4.2 kW.

It is mandatory for all newly connected energy-consuming assets to participate, and at the same time it is not allowed for DSOs to refuse or postpone the connection of these assets due to insufficient grid capacity. For participation, customers benefit from a reduced grid fee.

Madeira, Portugal[40]

The electricity company EEM installed centralised BESS on the island of Porto Santo in 2020 (4.3 MW /3.3 MWh) and on the island of Madeira in 2022 (15 MW / 16.4 MWh). Both systems provide support for frequency regulation, voltage control and active and reactive power. In addition, the BESS in Porto Santo has grid forming capabilities as well as providing inertia to the system. The use of the centralised BESS not only decreased curtailment of renewable energy generation but also improved the quality and security of supply to the customers in these two electricity systems.

[39] For more information on the implementation of Article 14a of the Energy Industry Act in Germany (Link)
[40] For more information on the EEM's experience with centralised BESS in Madeira, Portugal (Link)

Integration of DERs is expected to help the reliability of the grid and decrease energy prices. While the integration of DERs helps the energy transition, its effect on the pricing depends on the regulatory framework and support measures, as well as electricity system planning.

End-consumer side management, including home energy management systems and the use of smart appliances. A home or building energy management system is the interface for the control of users' devices. Aside from energy pricing information, the grid can provide demand limit information or command. Energy smart appliances allow consumers to shift electricity use depending on their preference, electricity prices, grid signals or other parameters. In this way, customers can contribute to the stability of the grid and potentially decrease their own energy costs. Interoperability of smart appliances, energy management systems and electricity meters, is extremely important to be able to accelerate the energy transition and allow decisions to be made using technology agnostic process. Europe is in the process of achieving agreement and commitment of appliance manufacturers to comply with interoperability principles through acceptance of the Code of Conduct for Energy Smart Appliances.[41]s' devices. Aside from energy pricing information, the grid can provide demand limit information or command. Energy smart appliances allow consumers to shift electricity use depending on their preference, electricity prices, grid signals or other parameters. In this way customers can contribute to the stability of the grid and potentially decrease their own energy costs. Interoperability of smart appliances, energy management systems and electricity meters, is extremely important to be able to accelerate the energy transition and allow decisions to be made using technology agnostic process. Europe is in the process of achieving agreement and commitment of appliance manufacturers to comply to interoperability principles through acceptance of the Code of Conduct for Energy Smart Appliances.[42]

Using interoperable appliances, energy management systems, and **smart meters** allows for demand-side management (DSM) implementation. DSM includes various actions for managing/shifting end-consumer loads and demand response. Demand Response requires real-time reaction of the loads to the unplanned grid needs. For Demand Response to be possible, installed smart meters should have proper functionalities, as discussed in the ACER report on Barriers to demand response.[43] Article 20 of the Electricity directive⍰ defines the needed functionalities of the smart metering system. Accordingly, smart meters: and demand response. Demand Response requires real-time reaction of the loads to the unplanned grid needs. For Demand Response to be possible installed smart meters should have proper functionalities, as discussed in ACER report on Barriers to demand response.[44] Article 20 of the Electricity directive[45] defines the needed functionalities of the smart metering system. Accordingly, smart meters:

- must be interoperable with both the consumer energy management systems and the smart grids,
- must accurately measure actual electricity consumption,

[41] Code of Conduct for Energy Smart Appliances (Link)

[43] ACER – Barriers to demand response, 2023 (Link)

[45] Electricity directive (Link)

- must provide validated historical consumption and non-validated near-real-time consumption to final customers at no additional cost,
- must account for electricity fed into the grid by active customers and make this data available to them or to a third party at no additional cost and
- must enable final customers to be metered and settled at the same time resolution as the imbalance settlement period set at the national level.

Additionally, energy community[46] implementation, which allows for collective management of energy consumption and generation by a number of end-users, could create opportunities for local balancing and avoidance of grid reinforcements. implementation, which allows for collective management of the energy consumption and generation by number of end-users, could create opportunities for local balancing and avoidance of grid reinforcements.

Sao Miguel, Azores, Portugal[47]

The utility company EDA, together with other partners, implemented a Vehicle to Grid project in Sao Miguel. The project included the use of 10 Nissan vehicles with a vehicle to grid capability for a year and a half. The project had three main goals: reduce energy costs for the client (time of use tariffs and peak shaving); provide services to the grid (peak reduction, frequency regulation, voltage control, demand response, etc.); compensate for variable renewable energy fluctuation in generation.

The lessons learned from the project include:

- If not optimised, EV charging can cause additional needs for the operation of the thermal power plant;
- If optimised, EVs can increase variable renewable energy integration during low-demand periods and thereby decrease curtailment;
- EVs with vehicle-to-grid capability can avoid the need for diesel-based generation;
- EVs with vehicle-to-grid capability can help regulate frequency, provided that the frequency control loops do not face communication delays;
- EVs with vehicle-to-grid capability can be used as a considerable storage source.

France[48]

This overview is based on ten different smart grid use cases, which include:

- Smart street lighting is to be used to decrease costs of energy and to provide local benefits, such as security or environmental.
- Use of demand side management of customer demand to provide flexibility to the utility, match demand to the local PV generation and decrease demand peaks. This provides examples of collaboration with industrial customers and with water management companies regulated by the government.
- Collective self-consumption to help manage the initial investment needed for RE through collective investment of citizens or businesses. This use case could also decrease local grid

[46] Energy communities as defined by the European Commission (Link)
[47] For more information on the EDA's experience with V2G implementation in Azores, Portugal (Link)
[48] A guide to widescale deployment of smart grids – 2023 (Link)

congestion by managing electricity demand and generation collectively in specific geographical regions.

The planning of the implementation of smart grids and, hence digitalisation of the grid has to be aligned with the planning of generation and understanding of the daily patterns in intermittency of the RE generation. Generation planning is also important when it comes to distributed PV generation. The importance of registering, monitoring and possibly remote managing DERs increases with the increased amount of distributed PV installations.

For example, Aruba had circa 900 distributed PV systems at about 14 MW at the end of 2022, causing congestion. These distributed PV systems typically cannot be managed by the utility company remotely. An additional example is Madeira, Portugal, with 770 distributed PV generation plants amounting to 10 MW. These systems also cannot be managed/controlled by the system operator[49] , creating unexpected disturbances to the electricity grid. generation plants amounting to 10 MW. These systems also cannot be managed/controlled by the system operator[49] creating unexpected disturbances to the electricity grid.

Intermittency of RE generation is best planned using forecasting tools. Grid operators should assess which data is needed to improve forecasting results for the expected generation and demand in their electricity system and include these needs in the planning of SES.

[49] Study on connection policies and management of energy systems under conditions of asynchronous generation in the non-interconnected islands, EU publication, the Clean energy for EU islands secretariat (Link)

Conclusions and next steps

The report assesses the current situation of the Smart Electricity Systems across the Dutch Caribbean islands with a focus on Bonaire, Sint Eustatius and Saba. While most BES islands have taken different actions in the process of implementation of smart grids, the first step of implementation of Advanced Metering Infrastructure (AMI) is ongoing in all islands.

Assessing the existing business case for the implementation of AMI in Sint Eustatius brings to light the benefits of implementing AMI in a joint effort with other islands. Sint Eustatius has an ongoing collaboration with Curaçao and Saba, with the expectation that the further implementation of AMI will be a joint effort of the three. Combining individual projects into larger packages of the same type of projects or aggregation of multiple projects can make it easier to find funding and help reach financiers or investors who might be focusing on larger projects only.

The report also reviews different aspects of smart grid implementation, which need to be taken into account from the beginning. Namely, when deciding on the AMI to be implemented, it is important to keep in mind its potential future use in managing distributed energy resources (rooftop PV, EV charging, batteries) and enabling demand-side management options. Hence, the decision on the type of smart meters to be installed should allow for these options. Additionally, implementation of AMI and Smart Electricity Systems requires not only a switch to more digital operation but also capacity building of utility staff to be able to maintain and manage the upgraded grid and its assets, analyse and use the acquired data from customers and use this data to coordinate with government and jointly design new measures to improve flexibility and reliability of the future decarbonised grid.

This report represents the first step in the support of the Clean energy for EU islands secretariat in the effort of BES (Bonaire, St Eustatius and Saba) islands to achieve full decarbonisation by 2030. The next step represents a Roadmap which will be prepared in collaboration with the BES islands Transition team to outline steps for the implementation of Smart Electricity Systems. In the preparation of the Roadmap, the synergies with other Dutch Caribbean and other Caribbean will be taken into account.