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Final Report:

Proof of Concept: Smart Solar Off-Grid

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Date of the Report: 08.06.18	**Contract Number:** 2015.09
Institution: ZENNA AG	**Country: Belize**

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Contents

1. Summary

Maximum of 1 page, containing the most relevant information; particularly:
Why was this project implemented (Needs in the partner country)?
What was implemented (project's content)?
How was the project carried out and what objectives have been achieved?
What do you foresee as further actions to be undertaken?

In 2014, it was estimated that over 10,000 Belizean's remain without electricity. The vast majority of these people reside in very remote communities. Their small population and geographical location make it technically difficult and uneconomical for the national electricity grid to provide electrical services. As a result, ZENNA AG in collaboration with Solar Energy Solutions Belize Ltd, hereafter called SESB implemented the project of Proof of Concept: Smart Solar Off-grid. SESB and ZENNA designed a centralized 24kW Hybrid Solar Off-Grid system for La Gracia Village in Belize. The modular Smart Solar Off-Grid System can easily be adapted and extended to increased energy demand in the future. The different components of the system have been sized to provide for the basic electricity needs of 42 households. The commencement of the project at the site was in March 2016 and by June 2017, 42 houses were electrified with renewable energy. Each house was provided with a meter and Pre-Pay-Card (RFID) to purchase electricity in pre-paid bundles that fit their financial abilities. Villagers were advised to use energy efficient appliances and tought which were the dos and don'ts. Additionally, to increase the community sense of responsibility, eleven (5 women and 6 men) residents of La Gracia Village were trained on how to operate and maintain the solar system. In January 2018, the Football Field, Public School and Water Board were connected to the system. This project is a huge improvement in the lives of 290 people.

2. Starting Point

Short description of the initial situation at the project's start.

Belize Electricity Limited is the national (and only) distributer of electricity in Belize; however, it is dependent on Mexico for over 30 percent of electricity supply. Ministry of Public Services, Energy and Public Utilities (MPSEPU) Strategic Plan 2012-2017 has the objectives to make use of Belize's significant renewable energy resources (biomass, hydro-electricity, solar and wind) to electrify the entire country and to achieve a low carbon economy by 2030. (Gischler,3). However, the energy sector faces economical, social, and technological challenges. There are approximately 47 villages without electricity and most of these villages use kerosene lamps and candle lighting. It is technically difficult and highly costly for the national grid to supply these remote villages with electricity due to their small population and distant location. MPSEPU is exploring the options for stand-alone systems in rural areas. However, there aren't many of these community systems operated in Belize that are fully functional. These systems typically fail due to lack of economical sustainability as in most cases there aren't enough funds to replace equipment such as battery banks. Reasons can be inadequate operator models, lack of flexible tariff structures for off-grid

systems, unpaid electricity bills or mismanagement. They also lack technological sustainability, as there aren't technically skilled people in the villages to troubleshoot and maintain the systems. By connecting with MPSEPU, SESB, and the REPIC (Renewable Energy, Energy & Resource Efficiency Promotion in International Cooperation) Platform Switzerland, a strong team of project partners and funders was formed and the idea of realizing a "Proof of Concept" for a functioning mini-grid became a reality.

3. Results

Description of the project's original objectives.

The key objectives of this project were to provide electricity to 9 households of La Gracia Village, be a proof of concept of an off-grid solar system, and complete the accompanying business model. As previously mentioned there are many Belizeans living in rural areas without the convenience of electricity. According to Senator Joy Grant, Minister at the time, in an interview in September 2014 –

"Last year Belize derived 57% of its electricity from renewable resources including hydro power and biomass. Our goal is to have renewable resources provide 80% of our country's energy consumption by 2020 and 95% by 2030. Belize has signed on to the United Nations (Decade of Sustainable Energy for All) in which we aim to provide energy to all our people by 2024." ("Belize to Boast,")

The Government of Belize has an ambitious goal; however, it has limited financial and technological resources. Contracts between the European Union and the Belizean Government allow Belize to take part in the 11th European Development Fund/National Indicative Programme (NIP) in 2017/2018. This EU program will support the energy sector of Belize as a key driver for sustainable growth. To take advantage of this program, the Government of Belize strongly depends on a proven concept for the electrification of remote villages. Therefore, this projects aims to pro-vide electricity to a few of these houses and to be that "proof of concept" of a fully functional off-grid system the Government of Belize needs. Accompanying this proof of concept, a business model is to be completed. The lessons learned from the im-plementation and the operation of this Pilot Project will be essential for the future rep-lications of the system. The pilot phase of 1 year will help to evaluate, determine and establish different Owner & Operation Models and suitable tariff structures for central-ized village solar systems in Belize.

4. Project Review

4.1 Project Implementation

How was the project carried out (approach, partner and project's main steps)?

ZENNA partnered with SESB, and the Swiss Government Platform REPIC, to gain access to the newest technologies available as well as the necessary funds in order to carry out a Pilot Project in Belize. ZENNA approached MPSEPU to select a location for the pilot. La Gracia Village had been identified as one of the villages that won't be feasible to connect to the national electricity grid from Belize Electricity Ltd before 2024. It is a farming community of 42 households and has roughly 290 inhab-

itants. This Farming Community is located about 25km northeast from Spanish Lookout, Cayo District, Belize. Therefore, it was selected to be the village to carry out a Pilot Phase. What better way to learn and educate Belize's energy sector than by experience under real Belizean conditions.

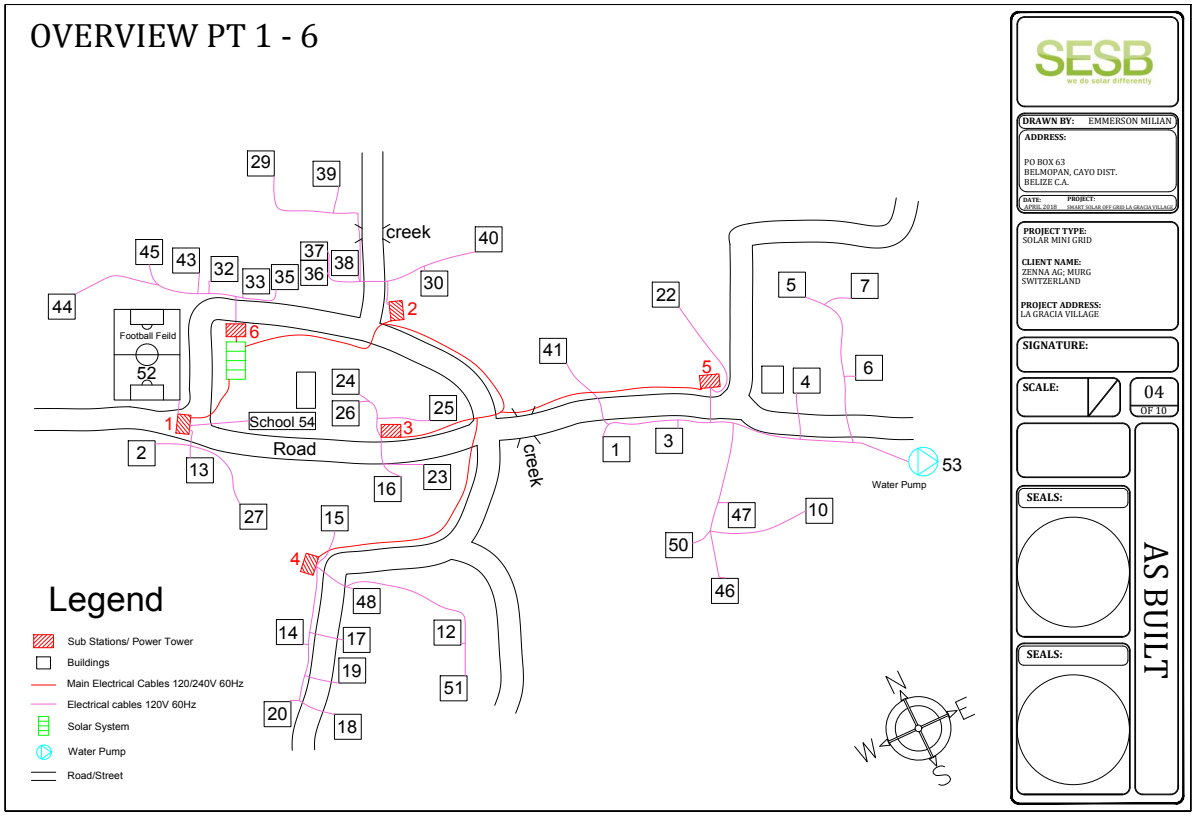
After having identified the location one of the most essential parts for this project was to ensure a strong community acceptance. SESB conducted a survey at La Gracia Village with the aim to gather information such as general interest in a possible electrification of the village, number of households, how many people per house and to get feed back on their estimated power use. Based on the outcome, a centralized 24kW Solar Off-Grid system intended to provide 45 private households, churches and shops with basic electricity was designed.

CONCEPT OF A SOLAR OFF-GRID CENTRAZLIZED MINI-GRID with 120 VAC BACKBONE

- ✓ Photovoltaic (PV): 24.48 kWp
- ✓ Surge Load: 40 kW / 3 seconds
- ✓ Continuous Load: 20 kW
- ✓ Power Storage: 2300 Ah / 48VDC / Gel Batteries
- ✓ Back-up Generator: 22kW / LP-Gas / Auto-Start
- ✓ Phases: Split-Phase 120/240 VAC
- ✓ Performance: 100 kWh per day – 36,500 kWh per year (average)
- ✓ Distribution: Underground
- ✓ Monitoring: Remote
- ✓ Energy Dispenser: Prepaid feature, 2000W max., individual caps adjustable

After the necessary project funds were secured, the equipment was procured and the installation started in March 2016. A shipping container was centrally set up on the schools' compound. It serves as a secure location for the solar equipment and as a base for the solar panel mounting structure. From there, a mini-grid with six power substations was established. Each substation host's five to twelve prepaid electricity dispensers (one per household) regulating the electricity supply to the respective houses. Wherever possible, big machinery was refrained from being used to establish the underground grid and rather counted on the manual labor force available in the community. 10 villagers were able to generate an income during the period of construction.

An additional financial contribution allowed for all the houses to be wired inside, as this would have exceeded the financial means of most of the villagers. By May 2017 the system was inaugurated, 42 houses were electrified with renewable energy and each house was provided with a meter and Pre-Pay-Card (RFID) to purchase electricity in pre-paid bundles that fit their financial abilities. This prevents the system operator from dealing with outstanding bills, and the villagers from overstretching their budgets. In order to promote technical sustainability, SESB trained 11 residents of La Gracia village to operate and maintain the solar system. Then in January 2018 Football Field, Public School and Water Board were connected to the system.



SESB operated the system together with the villagers for one year (May 2017 – April 2018). The lessons learned during this period were the base for recommenda-

tions made to MPSEPU in terms of Owner & Operator Models as well as flexible tariff structures. The system has been handed over to Belize Electricity Ltd for further operation.

4.2 Achievement of Objectives and Results

To what extent were the objectives achieved? Which results were achieved?

The Smart Solar Off-Grid pilot project fully accomplished its 3 main objectives. Firstly, one of the objectives was to provide electricity to 9 households of La Gracia Village. This aim wasn't only met; it was exceeded. The number of houses that were electrified was 45 (42 residential homes, 1 football field, 1 Water Board & 1 School).

Secondly, it successfully provided the "proof of concept" of a functioning mini-grid the Government of Belize needed in order to gain the financial support of the European Union (EU), for future electrification projects in the rural areas of Belize. Having gained access to these funds MPSEPU is now moving forward by preparing request for quotations for the electrification of other remote villages.

Thirdly, the business model was effectively completed and was well received by the villagers. The implementation of a sustainable system, which maintains social equality and creates an environment where all villagers can buy electricity according to their financial means, was effectively achieved. Instead of installing regular power meters, the research lead to so called Energy Dispensers especially designed for remote centralized mini-grids. They can limit the amount of electricity available per day per house (kWh) and they can cap the peak capacity per household (W) at any given time. Whenever the amount of electricity for the day is used up or a too big appliance is connected, the power goes out in the respective house. Not only does this protect the system from being overloaded by individuals with high consumption or big appliances, but it also allows the system to run smoothly during peak times and to

keep the generator hours low on cloudy and rainy days. This concept was such a success that we only had one blackout throughout the entire year.

The caps for all residential households are the same “Residential” category, while the shops and churches fall into a separate “Commercial” category with higher allowances. By giving the consumers equal amounts of electricity, this concept prevents wealthier villagers to buy and spend all the electricity available.

Then by implementing the prepaid function the villagers can purchase electricity in prepaid bundles that best fit their budget. Higher purchases don’t lead to more electricity available; they just enhance the time period before the next purchase becomes necessary. This allows for proper financial budgeting for the consumer as well as for the system operator and it avoids arrears management altogether. By implementing this innovative technology especially designed for remote mini-grids, many of the challenges faced in other similar projects were avoided. Moreover the system concept allows for future modular extension or for replication in regions where grid access is not feasible.

Through this pilot phase ZENNA’s partner SESB gained knowledge and experience, which will remain available within the country of Belize and will be very useful to replicate these mini-grids in other rural areas.

4.3 Multiplication / Replication Preparation

What preparatory work was carried out for the multiplication and replication within the project’s framework?

Several steps from start to finish were taken into consideration for the replication of the project. Initially, it was made sure that the project is a part of the Belize Road map of electrification and that there were other suitable locations for similar projects in Belize. Subsequently a concept that could be implemented anywhere was chosen. For instance, the container solution is one that is flexible. It can be placed anywhere and it should be able to work. Plus the system components worked with are of well-known and well-established manufactures. These manufactures’ guarantee maximum and sustainable efficiency for years. Throughout the pilot phase proper docu-

mentation was kept. At the end a report of all the findings, challenges, and lessons learnt were made available to MPSEPU and BEL, which is the current operator of the system. The knowledge exchanged, and recommendations provided to them will aid in smoother reproduction of this mini-grid.

4.4 Impact / Sustainability

Which impacts were already noticeable up to the end of the project?

This project has had a positive impact in the lives of 290 residents of La Gracia Village. A needs-assessment done in 2015 showed that the villagers were desperately waiting for electricity. Lighting and refrigeration were benefits they were hoping to receive. The 42 households are now electrified and are enjoying led lights, fridges etc. Children are now able to study during dark hours and the villagers are no longer using kerosene lamps. Electrifying the village has made way to mobile communication improvements. Most residents have cell phones despite the low coverage in their area.

The Smart-Off-Grid system is contributing to community involvement and education with the connections of the football field, the village water pump and the public school to the system. The water pumping station was operated with a gasoline generator approximately two hours per day. By connecting the water pump to the solar system, the gasoline generator is no longer necessary to pump water to the cisterns. The water board is saving BZD$140 per month which they can now invest in infrastructure for water distribution. At the same time the connection of the water board serves as a dump load for excess electricity. The lighting of the football field provides community unity and the kids and even adults now have a safely lit field to play and exercise. They are hosting football tournaments, which are generating money for the villagers through the selling of food to spectators etc. Besides, it's noticeable that with electricity in La Gracia, more villagers moving back to the village. This project has had measurable improvements in living standards of the villagers.

5. Outlook / Further Actions

5.1 Multiplication / Replication

What are the next planned steps?

What is being done to promote multiplication / replication?

Which hurdles need to be overcome in order to have successful multiplication / replication?

The Ministry of Public Service, Energy and Public Utilities can now move forward with rural electrification with access to €13.5 Million from the EU and a grant received from United Arab Emirates(UAE)-Caribbean Renewable Energy Fund. On January 14, 2018 delegates from Belize and the Government of the United Arab Emirates met to announce the emPOWER for Rural Electrification Project. This Project aims to provide 344kW of solar PV and battery storage in rural villages that currently do not have access to the national electricity grid. The Ministry has identified the 3 villages to be electrified, Indian Creek, Golden Stream, and Medina Bank and they are now preparing Requests for Quotations (RFQ). ("Belize receives Grant,") Surely more villages are about to follow.

Furthermore, the system of La Gracia is being used as a role model to be shown to many entities working with in this field such as Rocky Mountain Institute, The Carbon War Room, the Clinton Foundation, FOCAEP, Deutsche Gesellschaft für Intl. Zusammenarbeit (GIZ), and cdw Stiftung gGmbH. Certainly the "Smart Solar Off-Grid" will be replicated in other areas of Belize or even other countries.

Though a well functioning solar system role model has been put in place and the funds are available, there are still some hurdles that need to be overcome in order for these multiplications to take place. MPSEPU needs to prepare and pass legal framework for flexible tariff models for off grids. For instance, the pilot project could only be done through a special agreement to work with a different/higher tariff. In Belize there is a law that all people pay the same rate for electricity. However, this rate is not sufficient to run an off-grid system commercially successful.

5.2 Impact / Sustainability

What are the expected sustainable effects (environmental, socio-economic aspects, CO2 relevance, resource efficiency, etc.)?

This micro-grid system offers long-term energy security while decreasing fossil-fuel dependency. By sharing one solar system with several houses the pollution and CO2 in the air is minimized. Starting from the source, the sun itself is a huge resource of clean energy without toxic pollution and global warming emissions. Also, the use of a micro-grid leads to less individual generators and oil lamps, which release toxins that are not only bad for the environment but are both costly and harmful to health of villagers. In return it was advised to the villagers to use led lights in their home, which don't release fumes and are more energy efficient. Fewer generators also mean less gas purchasing runs to the nearest town, Spanish Lookout and fewer toxins in the air will increase health conditions. On the other hand socio-economic effects include maintaining social equality and overall decreasing energy costs for villagers. The caps for all residential households are the same throughout the village. This concept prevents wealthier villagers from purchasing and spending all the electricity available. More income does not lead to more access to electricity. Besides, there is one standard affordable rate for all.

6. Lesson Learned/ Conclusions

What are this project's main findings and conclusions?
Which recommendations can be made for similar projects, or within this context?
Interesting observations within the project's context: Which of your personal impressions would you like to share?

Findings

The project of Proof of Concept: Smart Solar Off-grid has been a huge milestone for Belize's rural electrification. The technical side of the system has been fulfilled and thus far working fine. Unfortunately on an economic perspective, one of the findings is that the beginning investment for the system hardware and installation cannot be recovered through electricity sales. However with a flexible tariff model the system can be maintained and reserves for replacement of future components can be built.

	Best case*	**Worst case****
Consumption per month:	2,920 kWh	1,073 kWh
Monthly costs and reserves to cover	BZD 2,609	BZD 2,609
Cost-reflective tariff	**BZD 0.89/kWh**	**BZD 2.43/kWh**
Sell (to end user):	BZD 0.40/kWh (legal tariff)	BZD 0.40/kWh (legal tariff)
Max. Revenue/month	BZD 1,168	BZD 429.20
Required subsidy/kWh	**BZD 0.49/kWh**	**BZD 2.03/kWh**

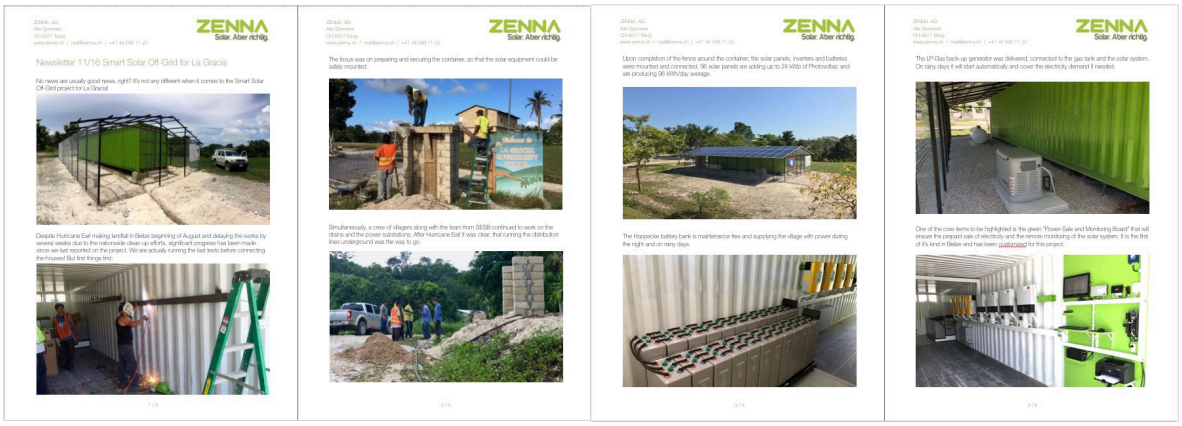
For example, the current legal tariff of BZD 0.40 (BZD 0.39 mean) for electricity in Belize is not suitable to run an off-grid system commercially successful. Likewise, the revenue generated in La Gracia through electricity sales at the current rate

of BZD 0.60, which was the special tariff agreement made for this pilot is not high enough to cover the operation and maintenance cost. The system implemented in La Gracia can produce an average of 2920 kWh per month. If all the kWh produced could be sold, the tariff would have to be set at BZD 0.89 in order to cover the O&M and Battery Replacement cost. Cross-subsidies and establishing legal framework for more flexible tariff models would be necessary. (i.e. lower tariffs between 9.00 am – 4.00pm / higher tariffs between 4.00pm – 9.00am).

Yet, in order to maintain the system at an affordable tariff it is inevitable to involve the local community in the daily operation task either through employment or in form of a cooperative. This helps to lower expenses such as mileage and labor cost. Only by lowering the expenses, opening the caps of energy daily allowance (EDAs) and increasing the tariff would there be enough income to cover the system's running cost.

As per the social outlook, the system was well received by the villagers. It was observed that after initial findings of how much electricity they could use or how much money they could spend on electricity it wasn't a problem for the villagers to have limited caps (reserved electricity). Due to having them involved from the very beginning and through out the pilot phase, they gave their full support. For instance, a self-training effect was evident when connecting the second Power Tower and all the others to follow. People had picked up knowledge already by chatting with the neighbors that had been enjoying electricity already. Every time a Power Tower was connected it was easier to train.

Another social outlook that proved to be effective was our newsletter feed. Throughout the Pilot of 1 year, Zenna issued several newsletters to provide updates on the status of our project. These newsletters were sent to project partners; who in return gave us positive feedback. They were well received because they had more images than words. Partners could see the progress of the project.



These newsletters were very informative. The use of this newsletter feed is strongly recommended for other projects to keep people updated.

Recommendations:

The first recommendation would be to find out the legal grounds before executing any given project. For instance, is there a legal framework to actually run a mini-grid system in that specific country? Also, who owns the land where the system is on? To avoid system failure due to legal obstacles, it's best to know the situation in that particular location. Another important recommendation is that the community be involved from the beginning. Village meetings held throughout the construction and pilot phase were key to ensure the continued support of the community. Having access to electricity for the first time had a huge impact on residents and sharing their experiences in these meetings were crucial.

Also, from this experience it's recommended to extend a short complimentary period for customers after they have been connected. In this project this aided in maintaining customer satisfaction. The villagers received two weeks of free power which allowed us to "play & learn" with the system without risking the villagers money. Additionally, if a cap system is implemented it is recommended to give them little from the beginning. If they are given low caps at first they can gradually be increased as the capacity and production being monitored allows. To maintain consumers happy it is always easier to give more but not to cut back. The caps can be optimized as wants or needs of consumers arise and system permits.

Interesting observations

An interesting development is that people are coming back to their village since there is electricity available. Surely there isn't anything more enjoyable than going back to your home.

Also, the villagers' business ideas are now coming to light! For instance, one of the villagers now has 2 small restaurants and 2 shops opened since the system is in place. What's more interesting is that as soon as the villagers got electricity the next thing they want is Internet. In a meeting carried out to discuss "Customer Survey", one of the topics brought up was the "want for Internet in their area". They want to join the crowd in this technological era. Surely with the convenience of electricity villagers will be finding other ways to improve their way of life.

7. References

Reference list of publications, reports, etc.

“Belize receives Grant from the UAE-Caribbean Renewable Energy Fund“, *Breaking News Belize*, 18 Jan. 2017. https://www.breakingbelizenews.com/2018/01/18/belize-receives-grant-from-the-uae-caribbean-renewable-energy-fund/ Accessed 22 May. 2018

“Belize to Boast Renewable Energy Source”, *The San Pedro Sun*, 10 Sep. 2014, https://www.sanpedrosun.com/community-and-society/2014/09/10/belize- boast-renewable-energy-source/. Accessed 23 May 2018

Gischler, Christian , et al,*The Energy Sector in Belize. Inter-American Development Bank 2014*

Preisig, Nadja, *Pilot Phase Report for GOB. SESB,* 2018

“Solar Off-Grid in Belize in La Gracia, Belize - Central America”, uploaded by Zenna AG. https://vimeo.com/251092758

8. Annex

When available: Reports, press articles, brochures, test results, etc

Newsletters by Zenna

A. Newsletter 03/16 Smart Solar Off-Grid for La Gracia
B. Newsletter 05/16 Smart Solar Off-Grid for La Gracia
C. Newsletter 07/16 Smart Solar Off-Grid for La Gracia
D. Newsletter 11/16 Smart Solar Off-Grid for La Gracia
E. Newsletter 04/17 Smart Solar Off-Grid for La Gracia
F. Newsletter 07/17 Smart Solar Off-Grid for La Gracia

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