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Final Report:

HelioHealth: A universal plug and play AI-enabled sensor for solar supply side management

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1. Summary

1. Why was it implemented?

Electrification and access to clean and reliable energy are the foundation of social upliftment and livelihood generation. Underdeveloped and emerging economies are going through a massive transition and also building their future habit of consumption and resource exploitation. Therefore, assimilation of cleaner and more sustainable processes in socio-economic factors, perhaps, one of the most relevant and effective steps towards achieving sustainable development goals. With the advent of new technologies, the electricity supply arrangement systems are expanding at an unprecedented rate; India had around 30 million un/poorly-electrified households[1] at the beginning of 2018 and it electrified almost all the households in the next one and half years (grid-connected and off-grid households). The efforts and achievement are remarkable but the mechanism of electrification of rural economies does not make economic sense in long term – the electricity utilities (DISCOMs) make the loss of INR 0.4 with each unit of electricity supplied to the rural communities and therefore, the majority of the rural areas suffer from long outage hours (> 12 hours, in case of the grid-connected supply) with poor quality of electricity. With the intensive electrification of rural villages, the consumption and demand for more energy have been increased by many folds which the utilities are not able to cater and the situation will remain the same for a decade or more unless there is a major structural change in the mechanism of energizing the rural communities. Moreover, access to clean and reliable energy to the rural communities revolves around the affordability of unit supply. Solar-powered distributed renewable energy systems are the strong contender which can truly electrify the far-flung rural areas at an affordable cost, but their sustainability depends on various factors controlling the supply of energy - system downtime, average operations & maintenance cost, availability of trained technical staff, and affordable monitoring & theft detection solution, etc.

2. What was implemented?

Our project focussed on validating the business hypothesis at a larger scale by making **solar energy much more accessible, affordable and cleaner.** We designed, developed, and deployed an AI-enabled IoT sensor, which is highly modular and plug & play, that can easily integrate with the solar panels, batteries, and electric loads (DC). The IoT hardware communicates with an analytics platform (cloud service) via a highly affordable and reliable SMS based connection (2G) even in remote areas. The analytics service runs deep learning algorithms, develops dynamic models adapted for the local situations, and provides relevant and precise prescriptive insights to the stakeholders. The project also focused on designing and developing an adaptive e-learning platform in the native language (Hindi) where a local technician enrolled, assessed, and certified.

3. The Achievements so far:

The project was implemented with two (Mera Gao Power & DESI Power) local off-grid energy partners and 5 residential roof-top grid connected companies in India. We selected around 30 sites (majority in north India and few in south india) where we have successfully deployed around 105 sensors so far. 25+ sensors were deployed on the batteries and the rest were directly installed on the solar panel. HealioHealth sensor successfully designed, manufactured, and adapted for the local conditions in India. An electronics manufacturer also shortlisted for manufacturing the sensors locally in India; the localized manufacturing reduced the cost of the sensor manufacturing drastically and we manufactured 105 adapted sensors locally in India. We also adapted the sensor as per Indian communication requirements and during the course of project implementation, we adapted algorithms to detect various scenarios - faulty conditions (panel degradation, shading, soiling, temperature effect, etc.), clear sky events, and prescribe a dynamic maintenance schedule for regular O&M activities. Moreover, training contents were developed and adapted for the online learning platform (HelioLearn) and relevant modules adapted in the native language. We enrolled and certified local technicians of our project partners. We also explored different types of business models and finally a service based business model (SaaS) was adopted for the customers. Moreover, we engaged with our partners in one of the most challenging times in history; when lockdown and human movement was at its minimum because of COVID - 19, the on-ground penetration of HelioHealth and fault localization helped our partners in minimizing the COVID exposure of their employees by reducing the dependency on field visits for fault localization and other operations (like billing and revenue collection).

4. The way forward:

So far we have received promising results on the ground. The affordable monitoring has significantly improved the abilities of our project partners; few of their sites have observed around drastic (50-80%) % reduction in the system downtime as well 50% improvement in their maintenance effort. However, to take this work forward and deliver a comprehensive Energy Asset Management (EAM) service, we would like to focus on the following points -

i. Load-side/demand-side monitoring and management service
ii. Develop and adapt mesh networking capabilities for our sensor. It will further reduce the cost of the sensor and make comprehensive per-panel monitoring affordable at the micro-grid/large scale plant level
iii. Further refinement in the climatic model to dynamically adapt the micro-climate at a higher level of accuracy

1. सारांश

a. इसे क्यों लागू किया गया?

विद्युतीकरण, स्वच्छ और विश्वसनीय ऊर्जा तक पहुंच, सामाजिक उत्थान और आजीविका उत्पादन की नींव हैं। अविकसित और उभरती अर्थव्यवस्थाएं बड़े पैमाने पर विद्युती-संक्रमण से गुजर रही हैं और अपने भविष्य की खपत और भविष्य में संसाधन शोषण की जरुरत भी बना रही हैं। इसलिए, सामाजिक-आर्थिक कारकों में क्लीनर और अधिक स्थायी प्रक्रियाओं को आत्मसात करना, शायद, सबसे महत्वपूर्ण विकास लक्ष्यों को प्राप्त करने की दिशा में सबसे अधिक प्रासंगिक और प्रभावी कदमों में से एक है। नई प्रौद्योगिकियों के आगमन के साथ, बिजली की आपूर्ति व्यवस्था प्रणाली एक अभूतपूर्व दर से विस्तार कर रही है; भारत में 2018 की शुरुआत में लगभग 30 मिलियन असिंचित घर थे और अगले डेढ़ साल (ग्रिड से जुड़े और ऑफ-ग्रिड घरों) में लगभग सभी घरों का विद्युतीकरण हो गया। ये प्रयास और उपलब्धि उल्लेखनीय हैं, लेकिन ग्रामीण अर्थव्यवस्थाओं के विद्युतीकरण का तंत्र, लंबी अवधि में, आर्थिक अर्थ नहीं बनाता है - बिजली वितरक (DISCOMs) ग्रामीण समुदायों को आपूर्ति की गई बिजली की प्रत्येक इकाई के साथ INR 0.4 का नुकसान करते हैं और इसलिए, बहुमत ग्रामीण क्षेत्र बिजली की खराब गुणवत्ता के साथ लंबे समय तक आउटेज घंटों (> ग्रिड से जुड़ी आपूर्ति के मामले में> 12 घंटे) से पीड़ित हैं। ग्रामीण गांवों के गहन विद्युतीकरण के साथ, कई गुना अधिक ऊर्जा की खपत और मांग में वृद्धि हुई है, जो वर्तमान बिजली प्रणाली पूरा करने में सक्षम नहीं हैं और यह स्थिति एक दशक या उससे अधिक के लिए बनी रहेगी, जब तक कि कोई बड़ा संरचनात्मक परिवर्तन नहीं होता है। ग्रामीण समुदायों के विद्युतीकरण का तंत्र। इसके अलावा, ग्रामीण समुदायों तक स्वच्छ और विश्वसनीय ऊर्जा की पहुंच इकाई आपूर्ति की सामर्थ्य के इर्द-गिर्द घूमती है। सौर ऊर्जा से संचालित अक्षय ऊर्जा प्रणालियाँ प्रबल दावेदार हैं जो वास्तव में एक सस्ती कीमत पर दूर-दराज के ग्रामीण क्षेत्रों का विद्युतीकरण कर सकती हैं, लेकिन उनकी स्थिरता, ऊर्जा की आपूर्ति को नियंत्रित करने वाले विभिन्न कारकों पर निर्भर करती है - सिस्टम डाउनटाइम, औसत संचालन और रखरखाव लागत, उपलब्धता प्रशिक्षित तकनीकी कर्मचारी और सस्ती निगरानी और चोरी का पता लगाने वाला समाधान इत्यादि।

b. क्या लागू किया गया था?

हमारी परियोजना, सौर ऊर्जा को अधिक सुलभ, सस्ती और स्वच्छ बनाकर बड़े पैमाने पर व्यापार परिकल्पना को मान्य करने पर ध्यान केंद्रित करती है। हमने एक कृत्रिम बुद्धिमत्ता (AI) - सक्षम IoT सेंसर डिजाइन, विकसित और तैनात किया है, जो अत्यधिक मॉड्यूलर और प्लग एंड प्ले है, और आसानी से सौर पैनलों, बैटरी और विद्युतीय लोड (डीसी) के साथ जोड़ा जा कर सकता है। IoT हार्डवेयर दूरस्थ क्षेत्रों में अत्यधिक सस्ती और विश्वसनीय एसएमएस आधारित कनेक्शन (2G) के माध्यम से एक एनालिटिक्स प्लेटफॉर्म (क्लाउड सेवा) के साथ संचार करता है। एनालिटिक्स सेवा गहन शिक्षण (Deep Learning) एल्गोरिदम चलाती है, जिसके माध्यम से, स्थानीय परिस्थितियों के लिए अनुकूलित गतिशील मॉडल विकसित करती है, और हितधारकों को प्रासंगिक और सटीक प्रिस्क्रिप्टिव अंतर्दृष्टि प्रदान करती है। परियोजना ने स्थानीय भाषा (हिंदी) में एक अनुकूली ई-लर्निंग प्लेटफ़ॉर्म को डिजाइन और विकसित करने पर भी ध्यान केंद्रित किया जहां एक स्थानीय तकनीशियन ने नामांकित, मूल्यांकन और प्रमाणित किया।

c. अब तक की उपलब्धियां:

यह परियोजना भारत में दो (Mera Gao Power[2] & DESI Power[3]) स्थानीय ऑफ-ग्रिड ऊर्जा कंपनियों और 5 आवासीय रूफ-टॉप ग्रिड कनेक्टेड कंपनियों के साथ लागू की गई। हमने लगभग 30 साइटों को

चुना (उत्तर भारत में और दक्षिण भारत में कुछ) जहां हमने सफलतापूर्वक अब तक लगभग 105 सेंसर तैनात किए हैं। 25+ सेंसर बैटरी पर तैनात किए गए और बाकी सीधे सौर पैनल पर स्थापित किए गए। HealioHealth सेंसर सफलतापूर्वक भारत में स्थानीय परिस्थितियों के लिए डिज़ाइन, निर्मित और अनुकूलित किए गए। एक इलेक्ट्रॉनिक्स निर्माता, भारत में स्थानीय स्तर पर सेंसर के निर्माण के लिए शॉर्टलिस्ट किया; स्थानीयकृत विनिर्माण ने सेंसर निर्माण की लागत को बहुत कम कर दिया और हमने भारत में स्थानीय रूप से 105 अनुकूलित सेंसर का निर्माण किया। हमने सेंसर को भारतीय संचार आवश्यकताओं के अनुसार अनुकूलित किया और परियोजना के कार्यान्वयन के दौरान, हमने विभिन्न परिदृश्यों का पता लगाने के लिए एल्गोरिदम को भी अनुकूलित किया - दोषपूर्ण स्थिति (पैनल में गिरावट, छायांकन, कालिख, तापमान प्रभाव, आदि), स्पष्ट आकाश घटनाएँ, और प्रिस्क्रिप्शन की गतिशील रखरखाव अनुसूची का प्रावधान, नियमित संचालन और रखरखाव गतिविधियों के कार्यान्वयन के लिए। इसके अलावा, प्रशिक्षण सामग्री को विकसित किया गया और ऑनलाइन लर्निंग प्लेटफॉर्म (HelioLearn) और संबंधित मॉड्यूल को मूल भाषा में अनुकूलित किया गया। हमने अपने प्रोजेक्ट पार्टनर के स्थानीय तकनीशियनों को नामांकित और प्रमाणित भी किया। हमने विभिन्न प्रकार के व्यवसाय मॉडल भी खोजे और अंत में ग्राहकों के लिए एक सेवा आधारित व्यवसाय मॉडल (SaaS) अपनाया। इसके अलावा, हम इतिहास के सबसे चुनौतीपूर्ण समय में से एक में अपने भागीदारों के साथ लगे; जब COVID - 19 के कारण लॉकडाउन और मानव गतिविधि अपने न्यूनतम स्तर पर था, तो HelioHealth और दोष (solar system fault) की पहचान और स्थानीयकरण ने हमारे सहयोगियों को गलती स्थानीयकरण और अन्य कार्यों के लिए फ़ील्ड विज़िट पर निर्भरता को कम करके अपने कर्मचारियों के COVID जोखिम को कम करने में मदद की (बिलिंग और राजस्व संग्रह की तरह)।

d. आगे का रास्ता और योजना:

अब तक हमें जमीन पर आशाजनक परिणाम मिले हैं। सस्ती निगरानी ने हमारे परियोजना भागीदारों की क्षमताओं में काफी सुधार किया है; उनकी कुछ साइटों ने सिस्टम डाउनटाइम में (50-80)% की कमी देखी है और साथ ही उनके रखरखाव के प्रयास में 50% सुधार किया है। हालाँकि, इस काम को आगे बढ़ाने के लिए और एक व्यापक ऊर्जा परिसंपत्ति प्रबंधन (EAM) सेवा प्रदान करने के लिए, हम निम्नलिखित बिंदुओं पर ध्यान केंद्रित करना चाहेंगे:

i. लोड-साइड / डिमांड-साइड मॉनिटरिंग और प्रबंधन सेवा
ii. भविष्य में सेंसर के लिए जाल नेटवर्किंग क्षमताओं का विकास और अनुकूलन। यह सेंसर की लागत को और कम करेगा और माइक्रो-ग्रिड / बड़े पैमाने पर संयंत्र स्तर पर प्रति-पैनल निगरानी को सस्ती बनाएगा
iii. जलवायु मॉडल में और अधिक परिष्कृत करने के लिए सटीकता के उच्च स्तर पर सूक्ष्म जलवायु को गतिशील रूप से अनुकूलित करना है

2. Starting Point

We started the project in September 2019. Initially, we selected two project partners in India and later expanded to another partner to implement the project on the ground -

1. DESI Power

DESI Power is an independent rural power producer involved in and committed to the socio-economic development of villages through the provision of electricity and energy services with a mission to reduce endemic rural poverty through local job creation and assured income generation. DESI Power currently owns around 30 micro/tiny and pico grids in Bihar, India. The customer profile of DESI power is quite diverse; DESI Power is catering to almost all types of rural loads - small commercial setups (RO water plant, cattle feed unit, and computer training center, etc.), rural hospital, individual household, and agriculture loads (pumping load), etc. DESI's units typically serve the load during the day-time and its biggest challenge is to maintain a lower downtime of their grids and provide quick service to the faulty systems. Due to the high cost of the existing monitoring, they depend more on customer complaints to fix any faults.

2. Oorja Development Solutions Ltd

Oorja is a mission-driven social enterprise based in New Delhi, India. Oorja provides integrated energy solutions to replace diesel engines used along the agricultural value chain. Oorja targets three types of users in the agricultural value chain -

i. Irrigation: Irrigation is a service for smallholder farmers. Available on-farm on a pay-per-liter basis
ii. Cold Storage: Cold storage for perishable goods as a service for smallholder farmers. Available at the farm gate on a pay-per-store basis
iii. Agro-processing: Electricity as a service for Agriculture and micro-enterprises. Available on the pay-per-kg rate at rural marketplaces

3. Mera Gao Power (MGP)

MGP develops and operates ultra-micro grids (pico-grids) for rural communities; MGP is creating a social impact by offering access to clean energy for basic daily energy requirements (powering up electric bulbs, mobile charging, etc.). Almost all the pico-grid sites of MGP are provisioned with a lead-acid battery unit and provide electricity to their customers during peak-load and late evening hours.

When we started the project, we required to work on multiple fronts; the starting of the projects and the state of our technology along with its challenges are described below

1. The hardware was not adapted for the Indian communication and environmental requirements

2. We had no clarity on sensor manufacturing in India - we need to develop manufacturing pipelines in India to reduce the cost of sensor that can be accepted by the local market
3. We had adapt the user interface for accessing the sensor data in a presentable format (mobile Apps and Dashboards)
4. We had to adapt the algorithms to conduct advance analytics on the sensor data that can detect faults, generate insights and prescribe according to local weather data
5. We were still exploring the requirements of the e-learning platform for the local technicians and we had no specific module that was adapted in the native language (Hindi)

However, we took all the bottlenecks one by one and started working on eliminating them.

On-site Pictures and Photographs

(a)

(b)

Figures: (a) Installation of HelioHealth Sensors across the battery units at MGP Site (Barabanki, Uttar Pradesh, India); (b) Pico-grid site, on a small shop's roof in Barabanki, Uttar pradesh, India

Figures: Micro-grid site in Araria, Bihar (DESI Power, India)


Figures: Battery Storage & Inverter units at DESI Power sites (in Araria, Bihar, India)

Figure: Heliohealth installation on a tiny-grid site in Bihar, India

3. Objectives

The HelioHealth project is focusing on providing an ecosystem of solutions using a combination of plug and play monitoring sensor, cloud based fault identification tool (HelioApp) and e-lessons for the ground staff to fix the problem (HelioLearn).

1. A plug and play Hardware (HelioHealth)

An affordable (~15 CHF) and plug and play sensor which can easily be plugged to the solar panels either at individual panels or at string level. This sensor communicates using SMS (for the basic phone user) and to HelioApp on smartphones.

2. HelioApp:

Machine learning based model to check production efficiency, predict fault and visualization on a smartphone App (HelioApp). This is a simple app, which provides visualizations, easy to understand statistics and action to fix.

3. HelioLearn:

This is an online platform (web/app), which provides e-lessons in local language to fix the problem. Once HelioApp identifies the problems, users will be recommended with relevant lessons to fix the problem. Furthermore, this app can be used to train on installations, O&M, good practices. This app also works in an offline environment where lessons, once downloaded can be used without the Internet.

The main objective of the project is to deploy 100 sensors at 15 locations at the DESI power site (Solar panels, appliances) and 5 locations (Solar panels, solar pumps) at Oorja sites. The project's expected deliverables are the followings:

a. An affordable monitoring solution to the mini-grids operators
b. Data-driven interventions for the O&M Teams using machine learning
c. Lessons on how to fix the more common problem.

During the project, the hardware is expected to adapt according to the project partners' needs, new AI-models to be integrated into the app (HelioApp) and e-learning are expected to be developed in the local language. These will be provided to the partners and their local technicians. After the completion of the project, around 100 sensors will be available with the local partners and they will have access to the HelioHealth platform on a long-term basis (the duration still to be determined). The local partner will become our first customer and during the project, the revenue model will be determined. Our partners will be free to use the sensors and install them anywhere at their site during the period of the project.

4. Project Review

1. Project Implementation

The project was implemented in a very strategic manner. We appointed a local project lead (LEDsafari Innovation Private Ltd.) to closely manage the project; this approach expedited our operations, imports related challenges from Switzerland and China and helped us quickly resolve the roadblocks. The project was organized in a systematic manner, with various teams constituted to implement and monitor the project effectively. The following teams were provisioned with their charter and agenda along with their time-bound deliverables:

- **i.** Project Steering Team - The team is responsible for brainstorming, finding challenges in the system & their possible solutions, identifying training needs, identifying new and relevant user scenarios or use cases, selecting and sizing the scalability of the project, etc. In addition to strategic thinking, the team is also responsible for resolving roadblocks, disputes, change requests, and any other matter as decided by the competent persons
- **ii.** Project Operations Team - The team is responsible for day to day implementation of the project as per the defined plan, reporting of the project on a weekly/daily/real-time basis (as desired), Hardware redesign and adaptations, resolve on-site issues and device installation, and logistics and accommodation arrangements for the LEDsafari representatives, etc.
- **iii.** Training and Capacity Building Team - The team is expected to identifying training needs, conduct skill gap assessments, help LEDsafari in designing the required content, share necessary resources, and training & capacity building of the professionals on the ground

We started the project in September 2019. However, because of the COVID - 19 and limited accessibility to the available agriculture sites (with solar-powered pumps) with Oorja, we decided to change the project partner. Immediately after the realization of anticipated problems, we entered into a partnership with another Indian organization: 'Mera Gao Power (MGP)'. Therefore we also tweaked the earlier planned objective of the project and decided to develop monitoring and analytics capabilities for the battery systems. Approval was taken in advance from the competent authorities at REPIC for this change. In addition to this, we faced certain challenges and road-blocks in the project implementation. <u>A few of the major road-blocks that we would like to highlight here are mentioned below:</u>

1. **Bringing a new approach to the O&M**: The contemporary O&M practices are quite standard and well cultured in the solar O&M industry. When we bought a new approach of evidence based O&M to the stakeholders they were quite skeptical in terms of its quick adoption. We adopted a pilot or demonstration based approach with extensive capacity building of the stakeholders to eliminate the bottlenecks

2. **Understanding the hierarchy in operations:** The O&M activities in the field are quite structured and organized; people usually follow a chain of command in order to ensure smooth functioning of the activities. To understand the chain of command, we adopted a participatory approach at each level of interaction and found the sweet spot for collaboration and interventional positioning
3. **Use of the tool by local workers/employees:** We bought technical solutions in the industry and people on the ground had no clue on what we were talking about. Therefore, training them on handling the tool was a mammoth task for us. Close collaboration and developing easy and digestible reading materials for them were the key to move forward. Therefore, our approach of empowering the user by building their capacities was very helpful in this sense
4. **Compatibility with the telecom providers:** India is a large country and it has multiple telecom providers. The telecom companies have regional dominance, in terms of connectivity, therefore, we needed to adapt the sensor as per the local telecom provider who has the most efficient telecom connection in that particular region.
5. **Revenue model calibration**: In the course of the project, we engaged with various categories of customers with diverse needs and problem statements. Therefore, based on their internal revenue mechanisms, we needed to adapt our pricing plan/scheme and revenue model. The various pricing schemes that we have innovated to satisfy various categories of customers are explained in the later chapters
6. **Hiring and arranging the necessary resources for the project:** One of the biggest challenges that we faced in the project implementation was hiring necessary human resources for the effective coordination and implementation of the project. The nature of our project includes extensive field visits and continuous interactions with the field staff (during the transition and capacity building phase). When COVID hit, we faced a challenge in arranging necessary support logistics in terms of travel, sensor logistics and accommodations. Moreover, the willingness of people to travel and interact with other people declined sharply because of the fear of getting infected with COVID

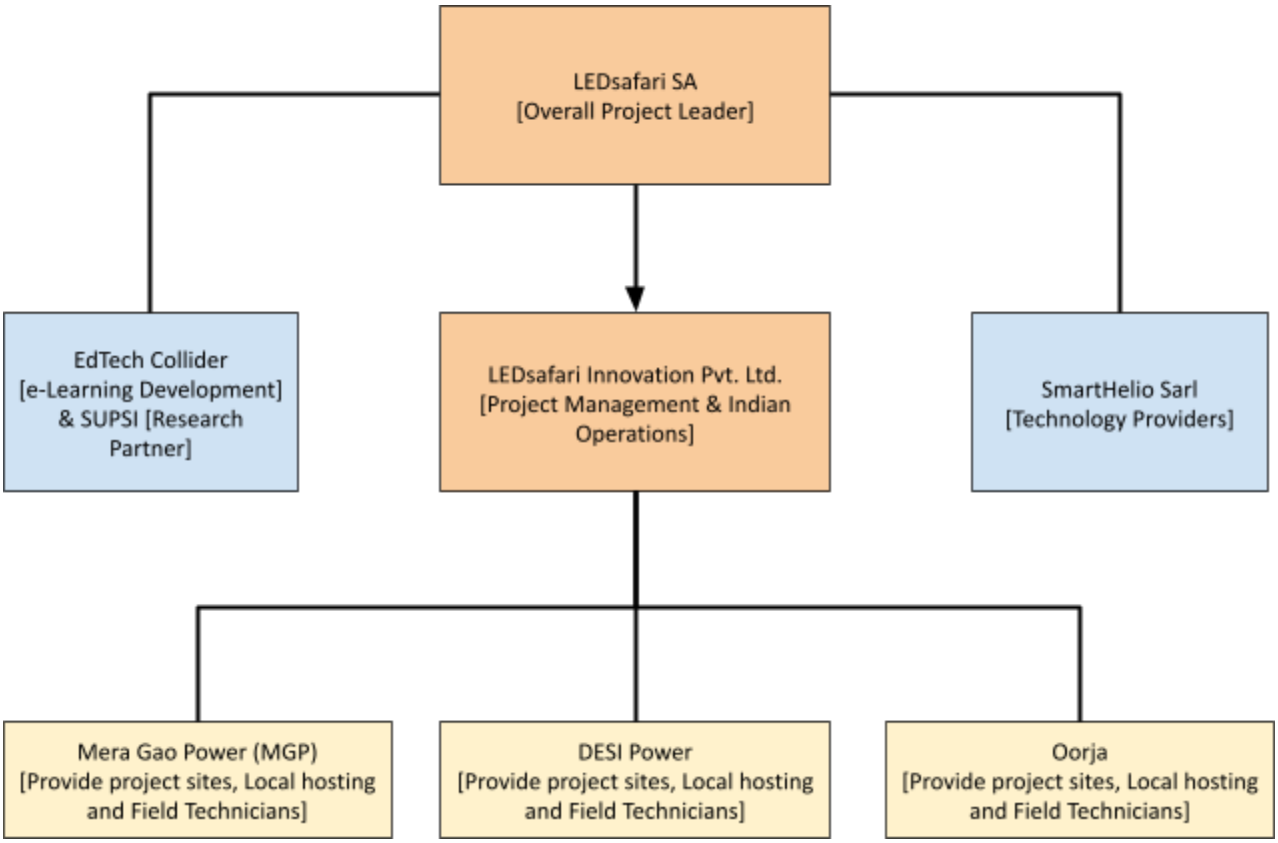


Figure : The Project Organization Chart

Figure : The HelioHealth Sensor

2. Achievements of Objectives & Results

We have successfully achieved the set objective of the project. The achievement of the major objectives can be summarized as below:

1. **Adaptation & upgradation of the hardware (HelioHealth):** The major objective of the first phase of the project was to adapt the hardware and make it compatible with the local telecom and environmental requirements. We shortlisted a few sites in multiple locations in India and validated the combination of our hardware and Indian telecom SIM at these sites. We further calibrated the communication protocol to make the hardware reliable in terms of network stability. We also successfully shortlisted around 20 project sites in this phase. The project was also taken as an opportunity to improve the overall functionalities of the sensor (HelioHealth). The on-field validated and upgraded HelioHealth sensor has the following key unique characteristics/use-cases:
    a. Extremely affordable per-panel monitoring solution (cheapest in terms of per sensor cost)
    b. Increased the data frequency from hourly to average 30 min.
    c. Increased the sensitivity of the sensor from 50 V to 90 V to take care of battery voltages.
    d. Uses SMS based reliable and affordable (2G) communication channels. Provides monitoring solution in far flung areas in a reliable manner
    e. 70% recyclable/reusable with very less carbon footprint (in its entire life-cycle)
    f. Edge computing device with local intelligence
    g. Adaptive based on historical patterns and cloud intelligence
    h. Programmable and remotely controllable data sensing and capturing capability
    i. Agnostic to telecom providers
    j. Plug and play, simple in handling and field management

Figure: Local technician at DESI power installing the sensor.

2. **Field operations and training & capacity building (HelioLearn Platform):** In phase two of the project we primarily targeted to achieve the objective of sensor installation at multiple sites and the development of training and capacity building resources for the field staff. We interviewed local technicians and collected their inputs and finally prepared materials that are more relevant for their usages. Moreover, in order to improve the consumability of the resources we translated the relevant learning modules in their native language (hindi).

3. **Localized sensor manufacturing:** One of major objectives of this project was to reduce the cost of sensor/HelioHealth manufacturing and this can be achieved by partnering with local suppliers and manufacturers. We explored multiple domestic Printed Circuit Board (PCB) manufacturers (#3) and based on their quality of manufactured product and cost, we shortlisted PCB Power India (www.pcbpower.com) for the manufacturing of our first bulk order (100 sensors).

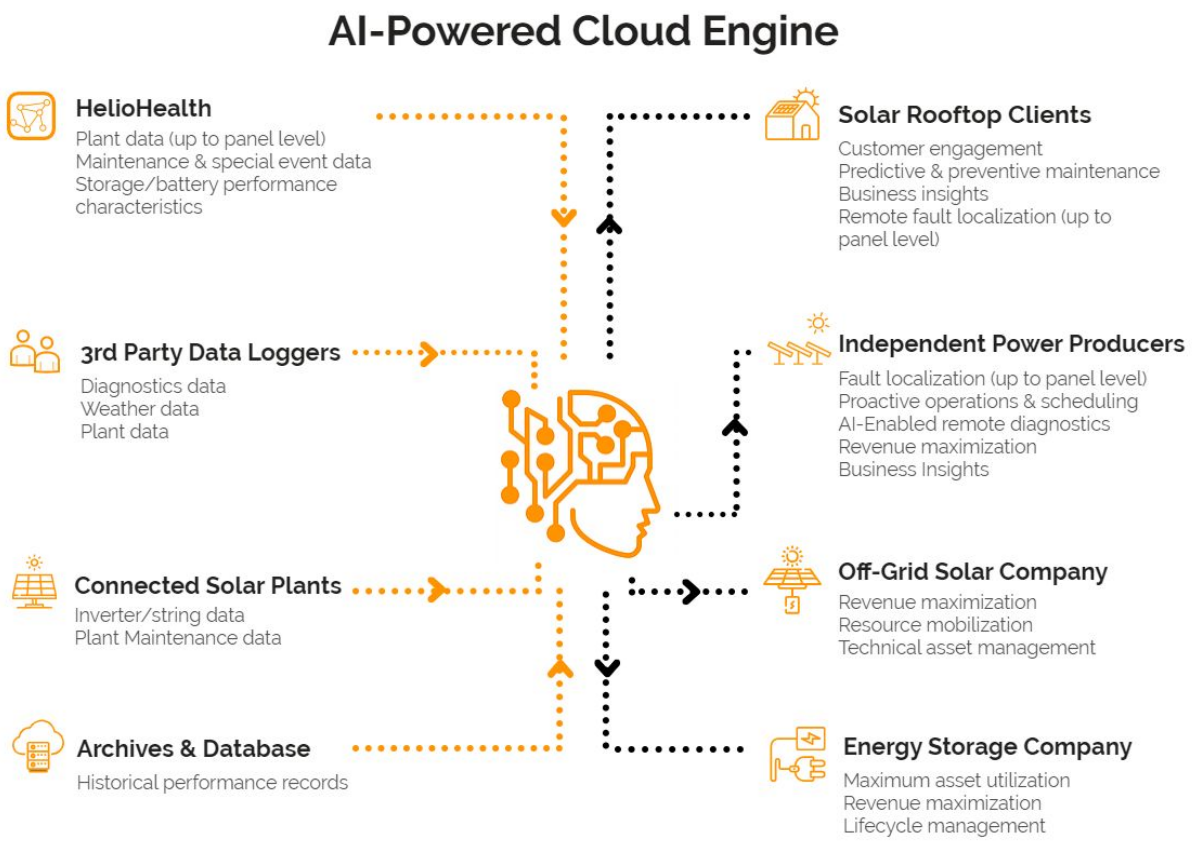
4. **Improvement of Artificial Intelligence (AI) algorithms:** We started collecting solar panel-level performance data, in significant amounts, after the installation of the sensors (HelioHealth devices) at multiple sites. We used the collected data to develop and further improve our analytics algorithms. We had developed machine learning models to further refine our insights and we used the collected system performance data to enhance the accuracy of machine learning models. At the end of the project we are able to generate comprehensive AI reports (PV Plant Performance/Diagnostics Report) for various configurations of solar plants.

5. **Development of HelioApp & cloud platform:** A smart and efficient usage of IT resources to improve the outreach and usability of our services by developing HelioApp along with HelioLearn is the major objective of this project. We developed an android application that uses sensor data for generating basic analytics for the relevant stakeholder and fulfills the requirement of affordable monitoring for off-grid and small scale solar installations. In the later phase of the project, we developed a cloud solution that can be accessed from anywhere in the world which can process the HelioHealth data to generate much richer insights (like PR analysis, shading analysis, AI reports, and energy loss analytics, etc.). Moreover, this cloud solution is also capable of processing high frequency inverter data and provides some advanced insights like differential and dynamic soiling rate calculation, degradation analysis, differential PR analysis, advance shading analytics, etc.

6. **Testing and validation of the business models**: The use cases offered by the sensor (HelioHealth) and cloud solutions can be leveraged by variety of users and stakeholders in the solar value chain (Engineering Procurement & Construction companies (EPCs), Asset Owners, O & M organizations, Monitoring companies,

etc.). We developed and tested around five business models with 5 different pricing schemes. We also partnered with various companies and organizations to test and validate these business models. A further detailed description of these business models is covered in the next section

The major achievement of the project is the development and validation of the AI powered Analytics ecosystem. The ecosystem can be summarized as below:



Note: A detailed summary on the Key Performance Indicators (KPIs) of the project is covered in the Annex section of this report

3. Multiplication or Replication Preparation

Amidst COVID 19 outbreak, the project was managed efficiently and almost all the targets achieved on time. During the implementation of the project, a variety of methods and innovations were adopted to resolve the local (operational and technical) challenges that were hampering the further multiplication of the project. The following methods/strategies were adopted to ensure the ease of multiplication:

i. Partnerships are key to streamline the operations of the project. We partnered with on-site companies (DESI Power and Mera Gao Power) who provided the project site and the technical support with on-ground person-power to execute

the ground activities. We also explored the overarching rural electrification and off-grid energy ecosystem in India and strategically collaborated with Smart Power India. Smart Power India, a sister organization of the Rockefeller Foundation, is a key financier of off-grid energy systems in India who helped us in validating the project hypothesis and expected outcomes from its implementation point of view in India. We also trained the local technician to install and maintain the sensors.

ii. The learnings from the project were further tested to grid connected systems (solar rooftops, C&I, Utility scale plants - IPPs) and Electric Vehicles, etc.

iii. We engaged with various stakeholders of the solar value chain, understood their pain points and developed multiple use cases to cater their specific needs. In the participatory approach, we sat with the customers, most of them were the OPEX[1] customers, demonstrated how our solution/technology could help them in reducing costs and generating extra revenue. We realized a bundling of specific services, personalized for a specific segment of users, is more relevant than simply offering the services. Therefore, we thought of repackaging our services in the following 5 different categories:

1. **A Fixed Sensor Subscription:** This service is offered at INR XXXX[2] (CHF XXX) per sensor per year which includes the communication cost along with the full replacement of the damaged sensors during the contract period. Clients get benefits of plant and panel level monitoring with some basic analytics
2. **A Monthly Sensor Subscription:** This service is available at INR XXXX per month (plus one time installation fees) without communication expenses and sensor coverage (that means the clients need to pay for the replacements of the sensor if it gets damaged at the site). Clients get benefits of plant and panel level monitoring with some basic analytics
3. **Complete Cloud Services along with Sensor:** The combination is offered at INR XXXX per year per sensor. All the cloud based services are available within this package. Clients get detailed cloud diagnostic services and insights based on the sensor data
4. **Combined Analysis Service based on Inverter & Sensor:** This service is available at INR XXXX per year per inverter-sensor. Clients get a detailed performance report based on the sensor and inverter data on a periodic basis and access to basic cloud analytics
5. **Cloud Service based on Inverter Data:** The service is offered at INR XXXX per inverter per year. Clients get a detailed performance report based on the inverter data on a periodic basis and access to basic cloud analytics

[1] These are the people who neither own any substantial asset nor they have done any capital investment. They simply operate the system/assets as per the agreed terms and conditions with the asset owner and generate the revenue.

[2] These numbers and values are confidential to the company. Therefore, we have indicatively mentioned "XXXX" in the report

4. The Impacts & Sustainability of the Project

Impact Indicator	Unit	At Project Completion
Installed Renewable Energy Capacity monitored and managed	In kw	330[3]
Additional units of energy produced because of the implementation of the project	In kwh per year,	36'000[4]
Additional greenhouse gas reduction	In kgs of CO2	48240[5]
Saving for the end-user in a year	In CHF	5136[6]
Number of beneficiaries	In numbers	730[7]
Number of technicians trained	In numbers	30[8]

[3] The project was implemented at 1 micro-grid site of 30 kw, 30 tiny-grids of total 50 kw and 10 rooftop sites of 250 kw capacity

[4] 10% improvement in the overall energy production of the sites observed. On an average the daily yield of our sites was around 3 kwh/kw (post installations)

[5] Assumption - People use polluting DG sets when electricity is not available. 1 kw DG consumes 0.5 liter of diesel and emits 2.68 kg of CO_2 in an hour[4]

[6] The average tariff rate of off-grid electricity supply in India is around INR 10 per unit and the electricity from DG systems costs around INR 20 per unit. This is an average value after considering the regional variation in tariff prices

[7] On an average, a tiny-grid impacts 5 people while the selected micro-grid directly affects 80 people. The rooftop systems were directly affecting 500 people.

[8] This includes the technicians of our on-site partners (DESI Power and Mera Gao Power) and some local youths who were not directly engaged with our site partners at the time of their enrollment

5. The Outlook and Further Actions

1. Multiplication & Further Replication

The learnings of the project are extremely valuable and crucial for the verification of multiple hypotheses that we had earlier at the starting of the project. A few of the remarkable achievements that can be easily scaled up to next level of wider adoption are the followings:

i. **Strategic Partnership -** As partnerships are crucial to the growth of companies irrespective of their state of maturation, we believe, the way forward is to get in strategic collaboration with key organizations and companies. We will engage with organizations who are promoting electrification in rural areas, like Smart Power India, TATA Trust, and Rockefeller Foundations, etc.. Moreover, we will also partner with panel manufacturers such as IB solar and become part of their distribution. ,We are also targeting to make our technology versatile and more market ready. In order to move in this direction, we have started collaborating with Giga size solar companies who contribute significantly in the global solar PV market; we have already signed pilots with few of the major solar energy companies in India and Europe.

ii. **Algorithm Development** -We had successfully validated our systems & algorithms, and started planning to develop the commercial scale services for the following use cases:

1. Panel level reliable monitoring at an affordable price
2. Solar Panel Degradation Analysis
3. BOS Losses Analysis
4. Shading Analysis
5. Temperature Analysis
6. Soiling Trend Analysis
7. System Design Flaw Analysis
8. Dynamic Cleaning Schedule
9. Dynamic Pollution Modelling & True PR Calculation
10. Battery Monitoring & Management
11. Consolidated Reports - Financial & Technical Insights, etc.

The biggest bottleneck that we are facing, in rapid adoption and scaleup of the technology, is the behavioural and cultural interia that our potential clients have. Our solution is based on the frontier technologies (Artificial Intelligence, Machine Learning, & Internet of Things) which are not very common around the solar industry. Therefore, clouded by poor awareness, the solar asset owners are not very much comfortable with the quick integration of our services. Based on our experience till now, we have designed

a sales process which is based on 3 steps: 1) simulation (free for a limited period) 2) demonstration (paid service to show full capability of the system and its impact on saving and increasing revenue) 3) Integration (paid, we take over the portfolio). We believe we can further improve the perception by strategic marketing and promotion of successful case studies.

i. **Long Term Manufacturing & Supply Chain Plan -** We have successfully completed the pilot for the development of sensors with a local electronics manufacturer in India. After validating the quality of the hardware, we decided to manufacture around 100 sensors in India. The India made sensors are successfully installed at various sites. We have also institutionalized the processes for handling a larger demand of sensors.

   1. **Design & Manufacturing of Sensors**: We successfully manufactured around 105 sensors in India. The made in India sensors tested at various sites (in India) in the real environment and found satisfactory. The quotation from the Indian manufacturer for a larger scale of sensor production compared with the quotations from the Chinese and European manufacturer. Financially and operationally the local made sensors preferred for the domestic application is India.
   2. **Calibration & Testing of Sensors:** We are developing a test bench to conduct the rapid testing of a large number of sensors. The test bench is under the last stage of validation phase which is expected to be delivered in a couple of months.
   3. **Logistics Plan:** A reliable and robust logistics system is very essential for ensuring safe and efficient delivery of the sensors. A set of logistics partners tested on multiple parameters (average cost, average delivery time, geographical presence, etc.) and shortlisted for the next level of engagement.
   4. **Distribution:** A successful distribution network can easily increase the penetration and outreach of products. We are exploring the possibility of potential collaboration with retail and wholesale solar equipment distributors in India and Europe. Our next target is to start this engagement on a trial basis and assess its profitability and overall sustainability.
   5. **Communication partner:** We have also partnered with telecom in India to provide bulk SIM and negotiated a fair package.

   We believe our next steps are to strengthen our capacity and operational strength to overcome the ongoing constraints in our business. With reliable partnerships and systematic structure we will be able to replicate our business model and ensure exponential growth.

2. The Impact & Sustainability

In the multiplication phase, we will also open our business to larger size micro-grids and grid connected solar systems. The learnings from the project enables us to develop algorithms which can provide solutions to multiple burning questions of larger and smaller solar installations. Micro-grids and grid-connected solar installations are very vital to the

overall energy mix of the world. However, the rapid adoption of grid-connected solar systems in far flung off-grid areas or in less densely populated regions is still a big challenge because of the operational bottlenecks faced by the developers. In the multiplication phase, we will clearly target the pain points of such developers and help them with the following challenges:

- **i.** Introduce higher level of automation in asset management
- **ii.** Simple actionable steps to resolve the faults locally
- **iii.** Training and capacity building of the local youths using our e-learning platform if developers decide to expend in such areas

Our close collaboration with rural communities and stakeholders of renewable energy value chain, helped us in building our internal capacities and understanding the local needs at a much granular level. Our growth story is aligned with the mission of democratizing renewable energy (solar) by empowering local communities. A training and learning program in native/local language opens the opportunities for local people (especially youths) to understand and appreciate the technology, which further improves the local ecosystem for entrepreneurship in solar and investments by larger organizations. Areas, with more aware customers and skilled local population attract investment and generate local entrepreneurs, which again promotes local economic activities, and creates jobs, locally, in a sustainable manner.

With a successful implementation of our solution, the system downtime can decrease by 80% which causes an overall improvement in system performance by 20% (in far-flung areas). The solution increases the system uptime and therefore, reduces the usage of diesel (in Diesel Sets). Indirectly eliminating the needs of burning fossil fuels, our technology promotes a cleaner and healthier environment.

CO_2 Saving Calculation- 1 KW DG is being used for 8 hours for 73 days (the annual downtime of the system is 20 %), on an average which consumes 0.5 litre of diesel per hour. One litre of diesel releases approximately 2.68 kg of CO_2. Therefore, the total amount of CO_2 saved per year will be –

$=73 \times 8 \times 0.5 \times 2.68$
$=782.56$ kg of CO_2

This is a conservative approach as Diesel Generators' size can vary and their usage hour can change. A wider application of our sensors will not only make the solar systems less polluting but also energy efficient in terms of delivery of energy units, which will further improve the economics of solar technology and make it more competitive in the energy market.

6. Lessons Learned & Conclusions

The learnings from this project are immense. We interacted with the stakeholders of the value chain and understood the requirements at the grassroot level. In the last one year, during the implementation of the project, the highlighted learnings can be summarized as follows:

1. Sensors are quite robust and perform well even in high temperatures during summer
2. Panel level data from HelioHealth gives confidence to the technicians
3. In off-grid space, billing and collection is the major problem. In the absence of an affordable monitoring and metering the entrepreneurs were losing almost 30% of the earlier collected revenue
4. The overall quality of the sensor is heavily dependent on the manufacturer and we need to carefully shortlist the manufacturer
5. The sensor is a true plug and play device, with very simple steps of installations, the field staff even the end users can easily install it
6. We were surprised that the local people were comfortable with English vocabulary and we used a mixture of English and Local Language (Hindi)
7. A well defined sales strategy is required for completely demonstrating the value proposition of the products in a cost-sensitive market. Hence, we adopted a three stage stage sales (Simulation, Demonstration and Integration) process for further scaleup
8. Customer are not only interested in the supply-side monitoring and analytics but also interested in deploying such technologies at the demand side including the AC systems
9. A dynamic and hybrid sensor communication mechanism that leverages both SMS and internet services is the way forward in terms cost effectiveness and reliability

Moreover, the selected case studies, learnings from the project and our conclusions are described below in much detail.

1. Case study battery monitoring: Mera Gao Power (MGP):

i. Business model: MGP creates entrepreneurs and installs solar (1 KW with 40 Ah lead acid battery) to cater to 20 small shops in rural areas, to provide 4 hours of electricity during the evening (1800-2200). The system is operated and maintained by the entrepreneur and total expected revenue is supposed to be CHF1200 per year where CHF600 is the entrepreneur's income and CHF600 is for MGP. However, due to the large number of the system (#10'000) located in a radius of 500 Km, it is not easy to maintain and keep control of the system by MGP as a result there is energy theft at night as well as bad maintenance leading to system damage (battery and solar). Currently, MGP is losing CHF 300 per system every year.

ii. Solution: We provided the sensor for the battery management and platform to detect possible faults. The power curve data helped to detect the theft at night as well as quantify kWh consumed at night. This helped MGP to determine revenue

based on kWh. Furthermore, voltage (V) data indicated battery health and current (I) data helped to understand the type of load. In case, voltage or current went away from the normal value, MGP staff could warn the entrepreneur.

iii. Impact
    1. Revenue Maximization: Revenue increased by 30%.
    2. Optimized movement of his staff: 20% reduce cost
    3. Design optimization: solar and battery sizing was improved based on demand and supply battery
    4. Predictive analysis: Cash flow and asset management based on the customer consumption pattern.
    5. Scale-up: Currently 50 systems are being monitored using our sensor. We have an order of 1000 sensors, however due to COVID19, this has been postponed.

2. The Algorithm Development & Calibration

The algorithm is adapted to specific Indian faults conditions and to Indian climatic models

i. **Clear Sky model:** A clear sky model has been developed for Indian continent, which determines the moment in a day when the sky is clear.
ii. **Shading detection:** Our AI model uses pattern recognition to determine the shade pattern on a panel.
iii. **Soiling pattern:** Our AI model can detect soiling and warn the user to schedule cleaning.
iv. **Dynamic Scheduling:** We have started combining various effects that hamper the performance ratio of the solar panel. Our AI engine dynamically analyzes the performance trend and recommends an optimized schedule to the O & M team. The optimized scheduling reduced the regular cost of O & M and makes sure that system is running at a higher PR
v. **Module temperature Analysis:** Our AI predicts the module temperature. This is very important especially for high temperature countries like India. A high temperature decreases the efficiency significantly. Very high temperature accelerates the degradation of the modules

3. The Hardware: HelioHealth

The sensors, hardware and AI models are finalized. Local technicians can install and maintain the sensors autonomously by using the app.

i. Sensor finalization
    1. Sensor sensing element (voltage upto 90 Vdc & current upto 25 Amp)
    2. Communication module: SIM868 has been used which works with all kinds of SIM cards available in India
ii. Sensor hardware
    1. Hardware casing supplier has been identified. This supplier is based out of Delhi
    2. Sensor manufacturer (PCB), based out of Gujarat, has been finalized.

3. Sensor connectors (MC4) are available in the local market in India, which are readily available

4. Artificial Intelligence Models

i. Clear sky model was finalized for the Indian condition.
ii. Faults such as soiling, shading, solar and battery health

5. Training & Capacity Building

i. Local technician's capacity building
    1. Local technicians were trained to install sensors.
    2. The LEDsafari team does hand holding on a video call for the first 2 times and then technicians have access to online instructions for further installations. In any case, technicians are connected with our ground team on WhatsApp where they can call us.
ii. New e-learning modules based on Indian needs were elaborated in cooperation with Local technicians:
iii. After conducting interviews with local technicians from DESI, Oorja and Mera Gao power and inputs from Smart Power India, the courses on HelioLearn platform were adapted (modify existing elements, add new topics) according to the local education and need. The following courses were adapted with new elements for the local technicians on HelioLearn platform
    1. Introduction to Microgrid: Lessons were focused on the Indian context and talks about unreliability of the grid and why Microgrid is important.
    2. Components of Microgrid: Special focus on identifying quality components such as solar panels, batteries, connectors etc. Indian market is flooded with bad quality components, hence this is important to determine the quality.
    3. Operation and maintenance of Microgrid: It was more focused on best practices of O&M. Few elements such as
        a. How to clean the panels?
        b. How to determine battery failure?
        c. How to check fault panels?
        d. How to use a multimeter to quickly determine the health of solar and the battery.

    According to our observation and the interview, the local technicians needed the course on "WHY" some components fail and how to fix them fast, hence operation and maintenance was the most important course.
iv. Current and new modules are translated into Hindi
    1. All the courses related to microgrid were translated into Hindi. Local technicians from DESI Power helped us in the translation of the content.

Moreover, the project has played a vital role in validating the technology and helped us in assessing the overall compatibility of the solution under the real world circumstances.

Images: E - Learning Platform (web-portal and mobile app) and Learning Modules in Hindi

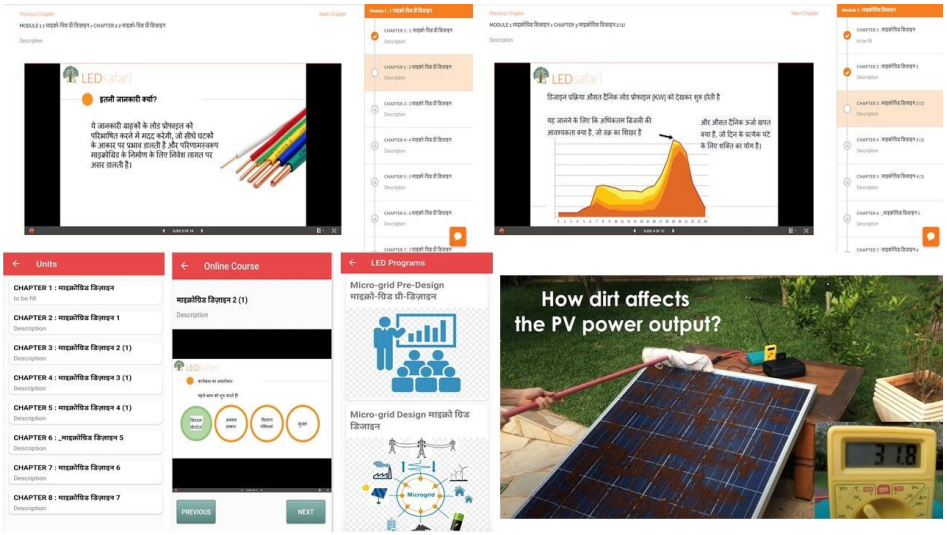
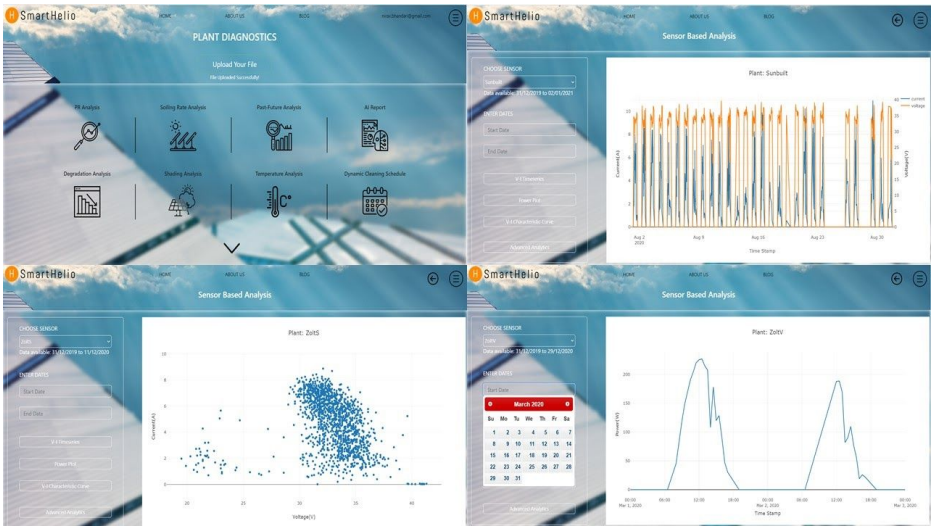


Image: Data Analytics Platforms



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8. Annex

1. Project Performance Monitoring Indicators (KPIs)

ACTIVITY	SUB-ACTIVITIES	STATUS	REMARKS
A batch of 30 HelioHealth sensors are installed on-site and adapted to Indian mini-grids	1. 25 Active sensors are in the field 2. Sensors damaged in the field 3. We have completed the target of 30 sensors	Completed	25 Active sensors on-site and 1 in DESI Power's custody. However, we have a total of 30 installations till today (6 sensors damaged at the site – 3 MGP, 1 DESI Power, 1 Green Park)
The HelioApp is adapted to the new information provided by the sensors in India.	1. Adaptation of Apps for new requirements	Completed	HelioSMS app has been developed and adapted for the Indian Requirements and a dashboard has been deployed.
	2. Development of a customized dashboard	Completed	
The HelioLearn app is functional on Indian smartphones and adapted to the needs of less-educated people	1. Development of HealioLearn App for the Indian technicians	Completed	HelioLearn App is now compatible with the Indian phones (app is compatible with almost all the leading android phones)
The algorithm is adapted to specific Indian faults conditions and to the Indian climatic model	1. Develop Algorithms for the Indian systems	Completed	
	2. Develop & Customize the climatic models to suit the Indian situation		
100 sensors are installed at 20 locations in India		Completed	105 Sensors locally manufactured in India and provisioned for the on-site partners (DESI, MGP and roof-tops)
Some sensors are adapted to flow measurements	1. Adaptation for the battery	Completed	The target has been changed to "Battery Monitoring". This has

	monitoring systems		been adapted and deployed at MGP sites.
New e-learning modules based on Indian needs were elaborated in cooperation with Local technicians	1. Preparation of Learning modules	Completed	The lessons were adapted according to the feedback from our on-sites partners and further translated into Hindi. These were very helpful during COVID times, as the staff could get trained.
	2. Enrollment of the Technicians	Completed	
	3. Certification of the enrolled students	In-Progress	
Current and new modules are translated into Hindi	1. Translate the relevant modules in hindi	Completed	
The sensors, hardware, and AI models are finalized. Local technicians can install and maintain the sensors autonomously by using the app	1. Conceptualize the models (hardware and AI)	Completed	
	2. Model & combination validation at the lab (or in a controlled environment)	Completed	
	3. On-field installation by the technicians	Completed	
	4. Validation of newly installed ecosystem	Completed	
A hardware manufacturer, an industrial partner as the potential distributor, and 3 customers other than the local partners are identified in India	1. Finalize the entire hardware supply chain in India	Completed	We have shortlisted local manufacturers in India and established a process for bulk manufacturing.
The 3 business models' approaches were tested and the one, which best fits	2. We have finalized 4 business models in India a. Solar rooftop	Completed	

India's scenarios, is identified.	b. Off-grid systems c. C & I solar systems d. Battery & storage solutions		
Conclusions are drawn and documented in the project final report regarding the added value of the system for mini-grid operators and end-users.		Completed	

Note: Due to COVID - 19 the field work for sensor installation has been delayed by a significant amount, however, we have successfully manufactured around 200 sensors, out of which 105 sensors are completely made in India.

2. Photo Documentation

Fig 1: Microgrid site (Araria, Bihar)

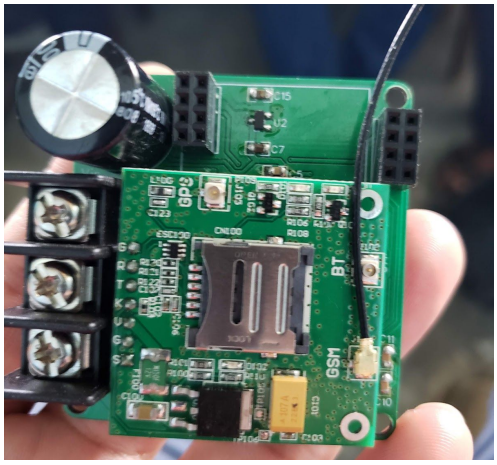

Fig 2: HelioHealth Sensor (internal)

Fig 3: HelioHealth Sensor (internal)

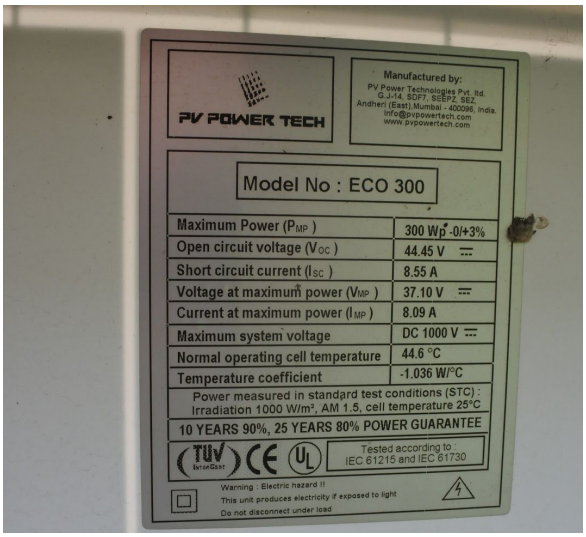

Fig 4: Panel Specification (Chakai Plant)

Fig 5: 30 kVA Inverter at Chakai, Araria (Bihar)

Fig 6: Battery packs at Chakai, Araria (Bihar)

Fig 7: Battery bank at Chakai, Araria (Bihar)

Fig 8: Sensor Installation in progress

Fig 9: Sensor Installation

Fig 10: Installed Sensor

Fig 11: LEDsafari & DESI Power Teams

Fig 12: Pico-grid site in araria, Bihar

Fig 13: 1.2 kW Pico-grid site in Araria, Bihar

Fig 14: Pic-grid Energy Storage unit

Fig 15: Water Treatment System, Araria, Bihar

Fig 16: RO Water Plant, Araria, Bihar

Fig 17: MGP's Pico-grid site (Barabanki, UP)

Fig 18: MGP's Pico-grid site (Lucknow, UP)

Fig 19: Solar Rooftop System

Fig 20: Sensor Installation During COVID outbreak

Fig 21: Installed Sensor

Fig 22: Cleaned panels, Karol Bagh, Delhi

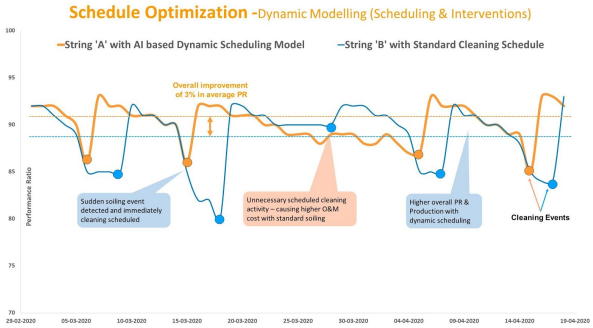

Fig 23: Dynamic Cleaning Model

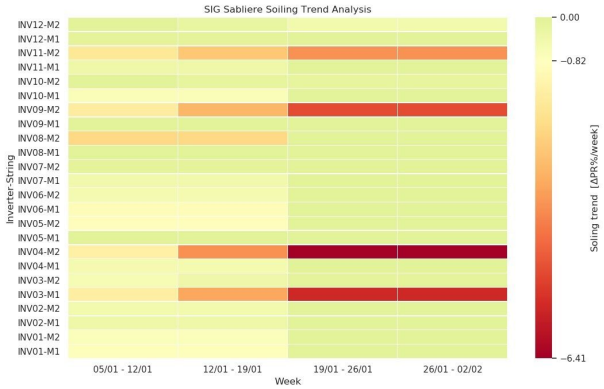

Fig 24: Soling Rate Analytics

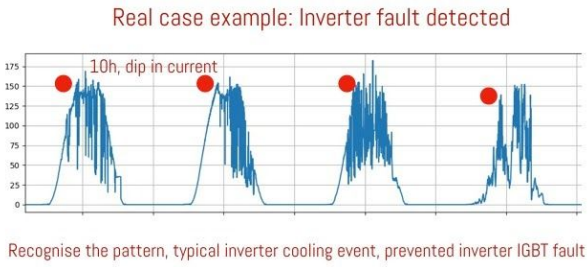

Fig 25: Inverter Fault Detection

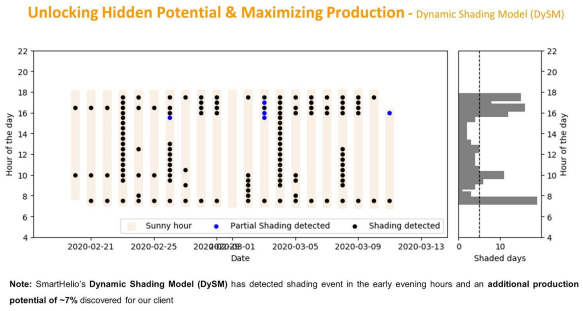

Fig 26: Shading Detection Algorithm

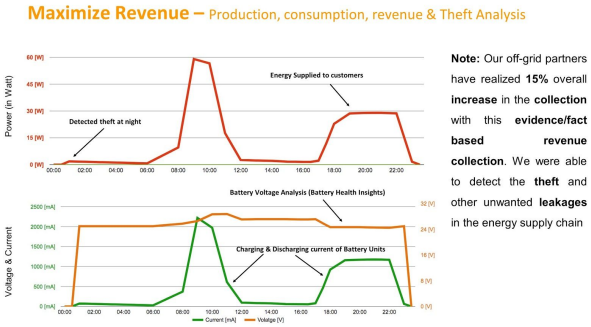

Fig 27: Off-grid electricity theft detection

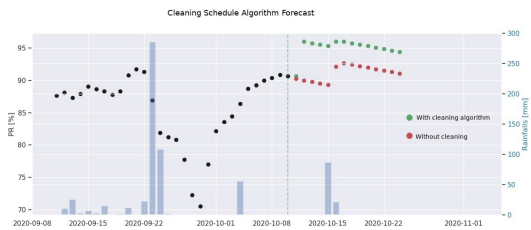

Fig 28: Cleaning Schedule Algorithm

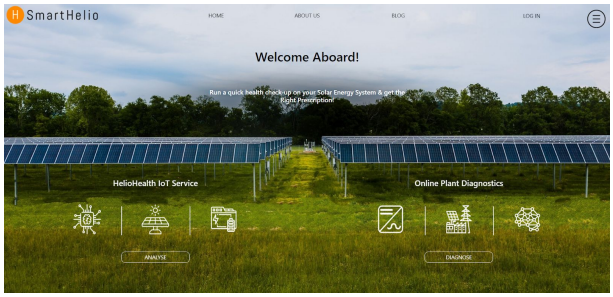

Fig 29: Online Diagnostics Tool (Home Page)

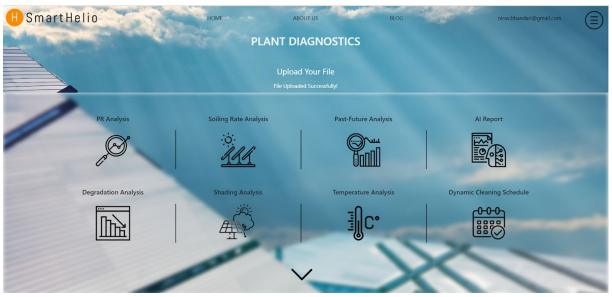

Fig 30: Online Inverter Analytics Services