POWERING AGRICULTURE:

AN ENERGY GRAND CHALLENGE FOR DEVELOPMENT

A report by

CLARO®

Low-cost, On-demand, Pay-as-you-go, Solar Powered Irrigation Service using Battery-operated EVs in rural agrarian regions of North India

Final Report

Powering Agriculture Innovator (PAEGC)

USAID FROM THE AMERICAN PEOPLE

SWEDEN

BMZ Federal Ministry for Economic Cooperation and Development

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Contents

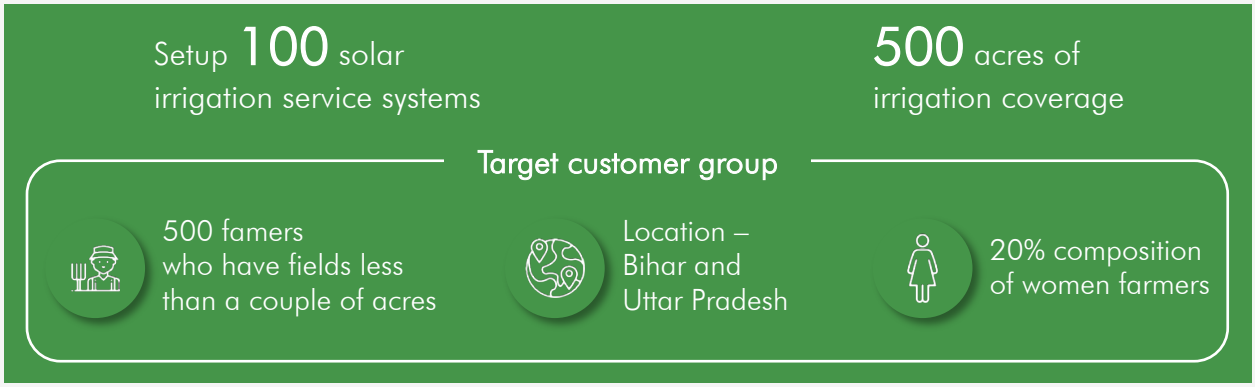
Project Background

Clean energy solutions in rural agrarian developing economies have the power to alleviate poverty at a massive scale by bringing energy access to solve agriculture productivity and simultaneously reduce greenhouse gas emissions by replacing diesel fuel – all at a scale never ever achieved before.

Claro Energy aims to offer a pay-per-use solar irrigation service using a portable solar pump. The irrigation service, a first of its kind, will be affordable, on-demand, and meets the needs of small and marginal farmers. The project's aim was to develop a solar powered irrigation solution that meet the needs of small and marginal farmers who don't own pumps and pay a hefty premium for irrigation from diesel pump sets provided by their neighbours or local dealers. The diesel pump sets are expensive to rent and operate and more importantly cause a lot of air pollution and greenhouse gas emissions. *It is estimated that 3 billion litres of diesel are consumed in India each year to pump water for irrigation and agriculture.*

Claro Energy conceptualized a low cost, on-demand and pay as you go, irrigation service in rural parts of India where electricity is scarce, and farmers mostly use diesel pump sets. The project received funding of US$ 500,000 from PoweringAg, which supports the development and deployment of clean energy innovations that increase agriculture productivity and stimulate low carbon economic growth in the agriculture sector of developing countries to help end extreme poverty and extreme hunger. Project work commenced in early 2016.

The goal was to help small and marginal farm productivity, reduce irrigation costs, and boost family income with clean energy solutions.



The approach was to design a movable solar system to maximize its utilization and reduce demand risks. In addition to design and manufacturing of the movable trolley, we built a stable Internet-of-Things (IoT) based transaction system that can work seamlessly in rural areas. The deployment was planned to allow for design iterations for the manufacture of trolley and technology incorporating learnings. Ultimately, the goal was to confirm the following:

a. Latent demand for such services in the rural farming community
b. Viable operating parameters and sales models are well understood
c. Compelling economics to scale up the solution

Lastly, the project targeted 50% reduction in cost of irrigation for the farmers from 120-180 Rupees ($2-3 USD) per hour that they pay currently.

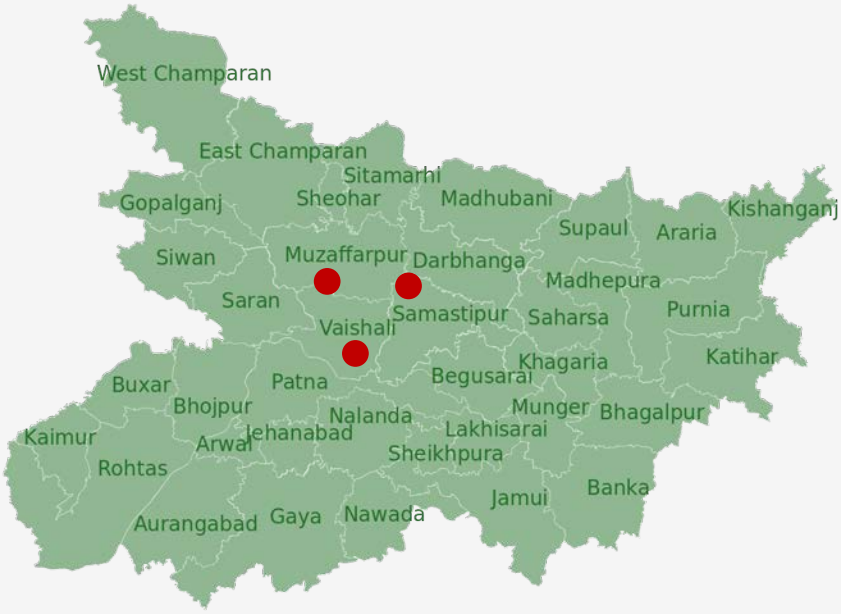
Activities and Accomplishments

Community selection

Communities were evaluated and selected based on the following criteria for solar irrigation system:

- A high use of diesel pump sets for irrigation with cost of irrigation more than Rs. 120 / hr
- The supply of electricity to the village is erratic and insufficient
- The farmers are small and marginal, have less than 2 acres of farm landholding and only grow 2 crops in a year with a significant number of farmers being women
- The bore wells to draw out underground water were present and that the water table was shallow for good performance
- There was a general sense of acceptance for solar irrigation among farmers with a desire to grow an extra crop in summer and a belief that shifting away from rice and wheat to growing vegetables will give them a much higher income

Three communities were selected and the map below provides the relative location of each community.



The table below provides the names of communities and the number of solar irrigation systems deployed in each community.

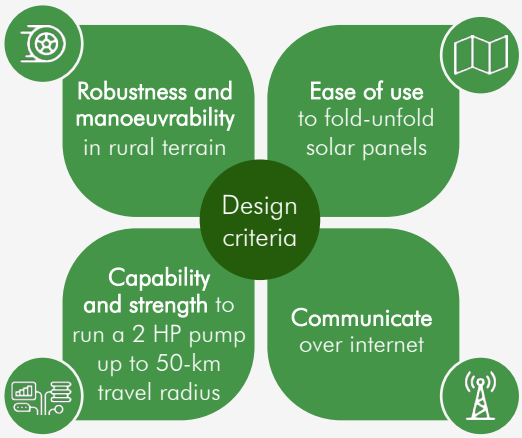
Community 1 Vaishali Small Farmer Association	**Community 2** Sumeena Foundation	**Community 3*** Jannirman Kendra
27 trolleys	7 trolleys	16 trolleys

* Community 3 also includes the Lease model deployed PatVans

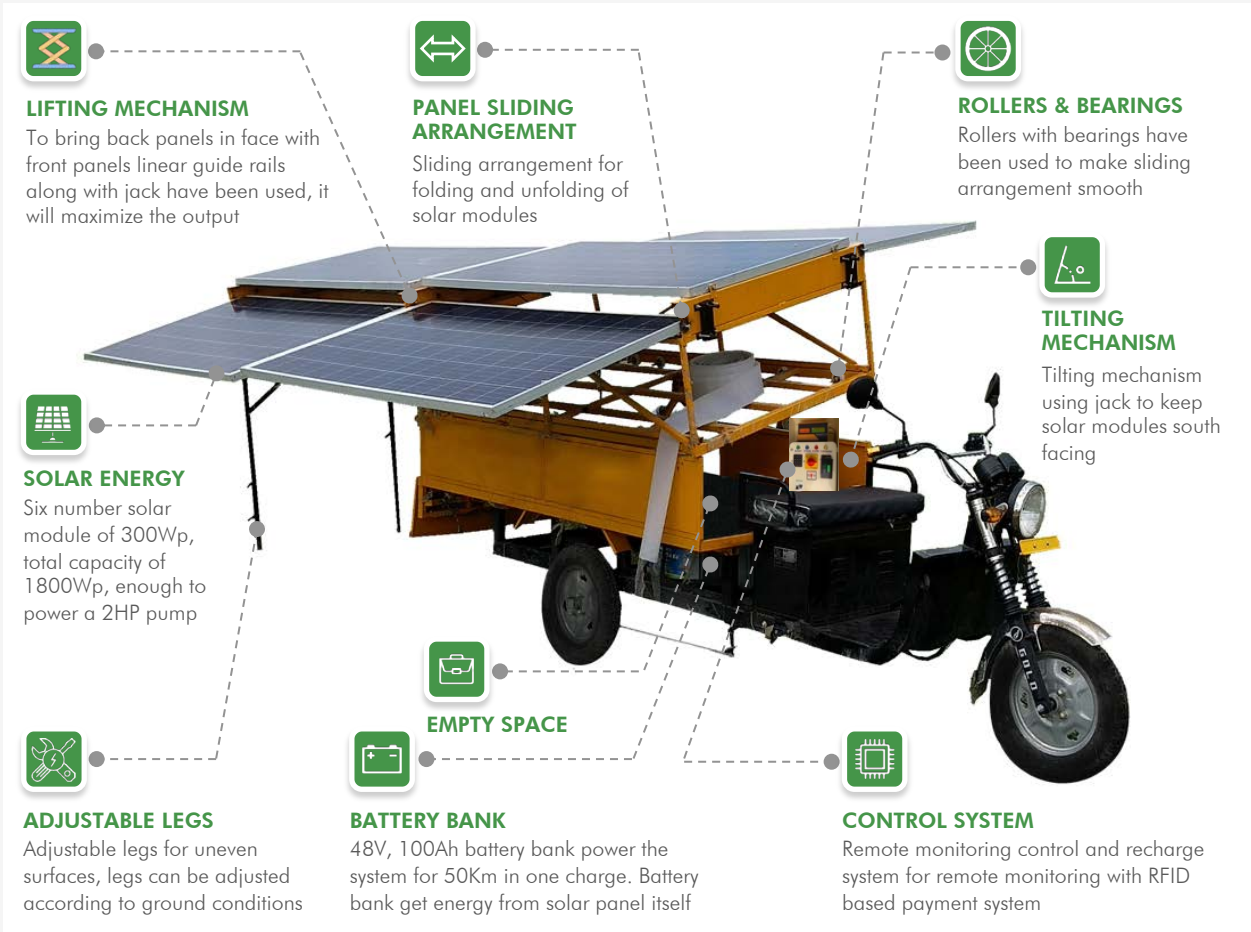
Building of solar trolley and connectivity (an IoT system)

The project started during the first quarter of 2016. Initial efforts focused on developing a solar power system mounted on a battery operated EV that could move from one farmer's field to other providing irrigation on-demand.

The EV was named 'mobile solar trolley' or portable solar pump or just trolley for simplicity. It was often locally referred to as 'PatVan' by the farmers. The term patvan (**पटवन**) in local language means 'to irrigate your crop' and fit the description quite well.



Mobile Solar Trolley, PatVan



The manufacturing of the trolleys was done in New Delhi as local vendors were either not available or were not satisfactory. When initial prototypes were deployed, it was observed, that the trolley was heavy and unstable in the beginning since the centre of gravity was higher. This exercise was repeated a few times till a more stable and robust design was achieved and the first set of 25 trolleys were then operational.

Product design summary

Major design iterations of different product forms are presented. The Models 1 and 2 were built as an attachment to an existing tractor. The Models 3 and 4 were designed as a complete unit using an electric vehicle (EV) for mobility. Model 5 eventually emerged due to a light version of solar panels being commercially available and viable. Model 5 provided further penetration into farm fields where trolley cannot go because of rural terrain.

MODEL 1

Detachable trolley mountable on a tractor with foldable panel setting

MODEL 2

Detachable trolley mountable on a tractor with improved panel sliding mechanism

MODEL 3

E-Rickshaw (battery operated electric vehicle) with solar panels

MODEL 4

E-Rickshaw (battery operated electric vehicle) with solar panels and improved Centre of Gravity, Panel movement, Panel inclination

MODEL 5

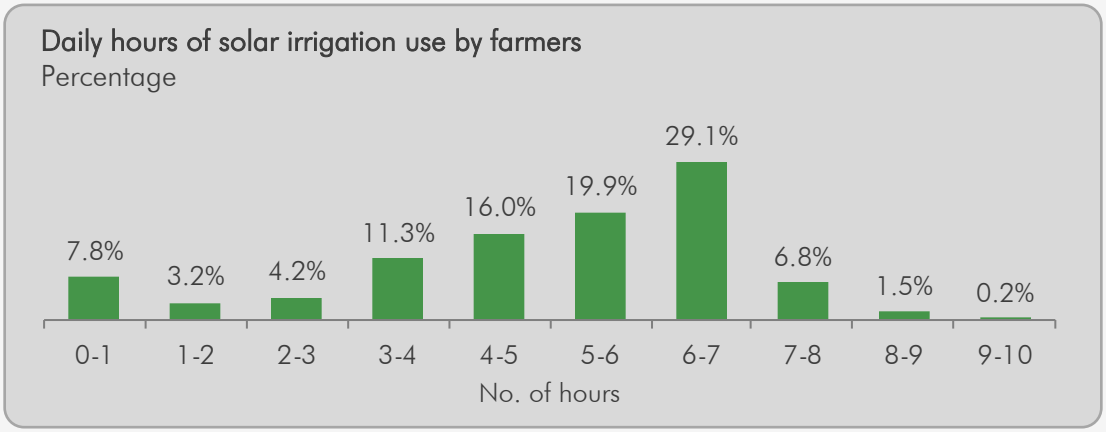
Portable solar irrigation using lightweight solar panels mounted on canvas sheets that can be folded and carried on a bicycle

Irrigation service methods

Irrigation service using a portable solar irrigation trolley

The solar irrigation trolley encountered several problems of stability, tilt of solar panels, support for heavy solar panels, wheel size, folding/unfolding system, and placement of pump. The trolley design went through several revisions to eventually converge to a stable and manoeuvrable trolley for rural roads.

While the initial prototype faced operational, maintenance and repair challenges, the irrigation demand from the farmers was very stable. The PatVan operations did prove a strong latent demand for solar power based irrigation services that were pay-per-use in nature as long as the data technologies worked.



It became clear that the farmers used the irrigation system for an average of 5-6 hours each day and earnings from the system were between 350 and 400 INR per day at 50% cost savings for the farmers over current diesel pump.

Irrigation service using a light weight and flexible solar panels

Solar irrigation trolleys were facing a lot of mechanical problems because of weight, rugged rural terrain, and poor interior roads. By 2018, light-weight solar panels had become cost effective that they presented a compelling solution for reducing the weight of solar panels by 10x. A new portable design in the form of a 'back-pack' was created that was light enough to carry solar panels on their shoulders or carry it around like a suitcase. This product form enabled farmers to carry the product themselves instead of the trolleys. Initially Claro operators created awareness and educated the farmers, they guided the farmers on how to operate the system. Gradually the farmers were in a position to do it on their own. This enabled reducing the cost impact of operator per system. The product could be laid out on field like a carpet and folded like a bedsheet. Then, the farmers could take this product form deep inside their fields which did not have access by road. This product form vastly improved the reach of the solar irrigation solution. More than one unit of 6 panels could be connected with each other to make a larger irrigation system. The EV trolleys could now carry 3 or much such systems into the field versus just one.

Irrigation service using nearby mini-grids

Often the trolley operations in a region created a stable demand for irrigation and almost completely displaced diesel (except in winter months). The irrigation demand necessitated the need for many trolleys in the community and became a became a daily requirement suggesting a permanent feature infrastructure such as a mini-grid with irrigation as an anchor load. Since the cost per Wp of irrigation trolleys is greater than that of mini-grid, we introduced 2 mini- grids in regions where irrigation trolleys had become popular and demand had stabilized. Operations quickly stabilized and communities became more interdependent on the mini-grids. The mini-grids operate on a pay-per-use basis as the flowmeter and technology components work because of stable data communication. The mini-grids provided 3 solar pumps and catered to a larger area in a stable manner. An additional advantage of mini-grids was that it became a trade point for farmers through which additional agri-and financial services can potentially be provided to poor and marginal farmers. The 2 mini grids were funded partly by Smart Power India (SPI), the arm of Rockefeller Foundation in India.

Business model & economics

The following business models were test tried / implemented:

Business Model	Description
Pay-as-you-go (flowmeter)	Pricing was set based on litres of water delivered to the farmers. A flowmeter connected to the solar pump measures the water discharged by the pump. The depth of underground water, prevalent irrigation cost with diesel pump-set and crop water requirement were used to determine local PayGo pricing which theoretically will vary with region. Farmers were given PayGo cards for identification, transaction monitoring and other data collection purposes. An operator was required under this business model. Due to problems with communication technology this model was later discontinued.
Monthly rental model	The monthly rental model is similar to how a leasing system would work. The trolleys are rented out to an NGOs (or a village entrepreneur) who would pay a fixed amount on a monthly basis. The operation of the system was in the scope of the NGO. In this model the performance risk was borne by the NGO. When the NGO has good understanding of irrigation needs of its farmer group, this model can work well.
Daily rental model	A variation derived from the monthly rental model was to charge daily rental since many times farmers rent the diesl pump-sets on a daily basis. The pricing was set at 50% discount to the diesel pump set. This model required an operator to coordinate rentals but one operator could handle many rentals. The farmers took the system from the local dispatch point and returned it at the end of day. This method works well for a village entrepreneur or a local village dealer.
Pay as you go (area-crop)	When the transaction IoT devices failed, the PayGo model was modified to work without a flowmeter. The pricing was set based on area of the field and the crop grown. This model was referred as 'per kattha' model referring to the area of the field which is measured in 'kattha' instead of acre. This model was better understood by the farmer as they were well versed with payment linked to area and crop. An operator was needed to coordinate like the daily rental model.

The monthly rental / lease model was quite successful with non-government organizations (NGOs) and farmer producer organization (FPOs). The NGOs had a better understanding of the irrigation need of their farmer groups and could run the trolley operations more effectively on the ground than us. Therefore, the NGOs derived greater value out of the system than we did. We provided about 10 trolleys to the NGOs to operate. Unfortunately, since our IoT system did not work we were not able to assess the benefit quantitatively.

Economics

Typical summary economics for the lease and pay-per-use models are given in the table below. While only one pay-per-use model is listed in the table, the economics for other pay-per-use models are similar and can be derived from the pay-per-use data.

	Mobile Solar Trolley (PatVan)		Ultra-light Flexible Solar System	
	Lease	Pay-as-you-go	Lease	Pay-as-you-go
Capex, $	3,000		1,800	
Opex – Operator, $	–	400*	–	200*
Open – Repair, $	200	200	50	50
Revenue (ARR), $	800	1,000	550	700
Breakeven (Yr)	5	7.5	3.6	4.5

* For trolley, 1 operator can support 3 PatVans; for flexible solar, 1 operator can support 6 flexible solar irrigation systems

Capex – The Solar trolley systems have a higher capex because it has an electric vehicle, a metal frame to hold solar panels, and battery – all of which add to the cost. In the Ultra-light version, the solar panels are flexible and are cost more but overall at the system level, the flexible solar irrigation system is cheaper.

Cost of Operator – Operator costs are a significant factor in the overall economics of pay-as-you-go model. The operator cost in the PatVan requires the operator to manage 3 PatVans to be economically viable. The lightweight solar system operator can manage 6 systems. The lease models have faster payback than Pay-as-you-Go because of the absence of operator cost. A big assumption is that if the system is leased, the NGO does not have to incur additional incremental expense to hire an operator and that the NGO has excess operator capacity. Therefore, build a business model that did not require an operator is an important factor to consider.

Business Model – Irrigation using ultra-light flexible solar panels, selling monthly or daily lease model via NGO/FPOs is the path forward. By using ultra-light flexible solar panels, initially the operator can handhold the users and guide them about opening, folding, connecting the system and gradually the goal is to put up the systems on daily/monthly lease model. Where the demand will be provided by the farmers to their representatives in NGOs/FPOs/communities etc. The users will be trained so that they can use it on their own without an operator. Also, three of these systems could be loaded in a PatVan and sent to farmlands, hence making the system more effective. The PatVan has a limitation to access the internal fields. The lightweight systems can be carried out into the fields that are not accessible to PatVans.

Repair Cost – The repair costs for solar mobile trolley are higher than that for ultra-light flexible solar systems because there are no moving parts in the lightweight irrigation system.

In summary, although the irrigation systems using lightweight flexible solar panels deliver lower revenues than PatVans or mobile solar trolley, they have better economics because of lower Capex and repair costs. Lease business model further enhances economics for both product forms.

Other related services

During PAEGC project, Claro Energy explored related services that would strengthen demand for clean energy irrigation services in the villages. Two successful initiates are described:

Market linkage services – Claro started offering crop purchase service to farmers in order to study the impact of irrigation demand and change in farmer behaviour when there is certainty of crop purchase. After a couple of seasons of crop purchase, the farmers were much accepting of irrigation schedules and solar irrigation solutions, and also willing to adopt better growing practices.

The learnings in this market were that farmers care most about:

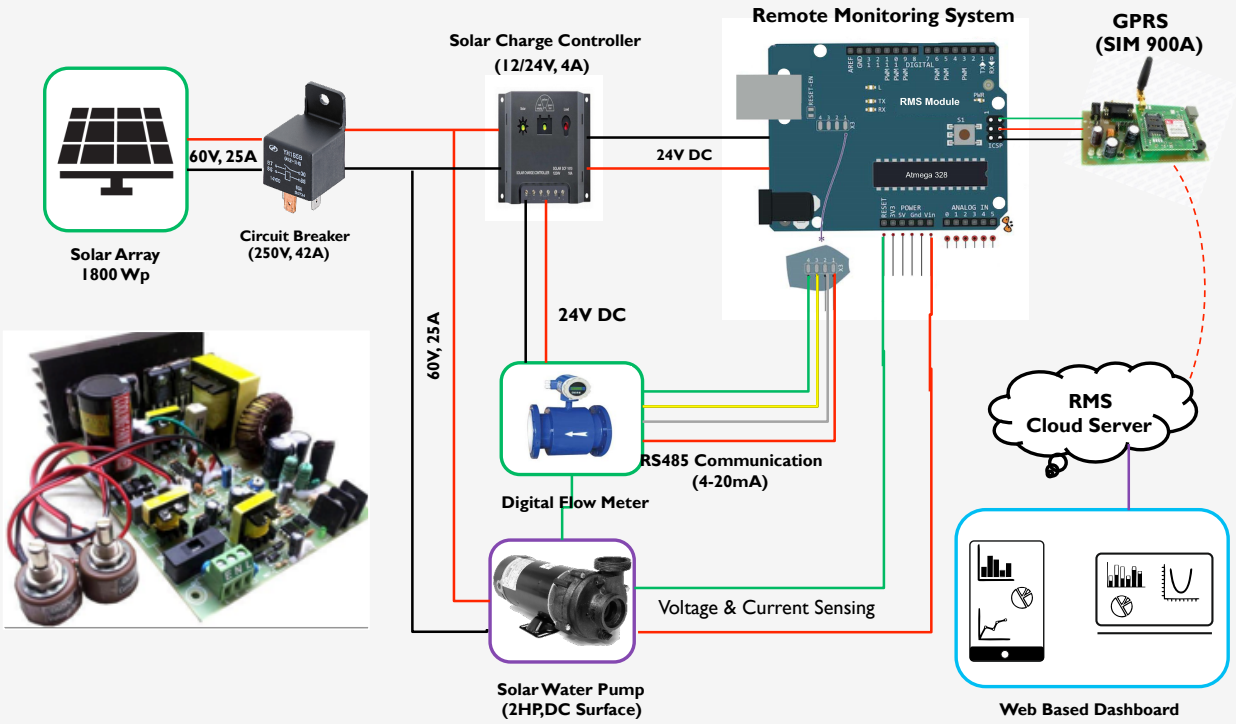
1. Selling at the highest market price
2. Offloading the entire produce with the least headache, and
3. Getting paid on time, ideally, upon delivery itself

Assurance of crop purchase was a strong driver to trying a clean energy solution, adopting any new crop growing practices, and working cohesively together.

Agri input services – During PAEGC project, Claro also collaborated with Jain Irrigation to provide tissue cultured G-9 variety of Banana saplings to a group of farmers in the community who showed intent to grow Banana. Claro also working with Bihar State Agriculture Departments which provided subsidy to the farmers for the purchase of saplings though agriculture university technology extension program. The farmers are currently growing their G-9 variety Banana crop, have taken irrigation using Claro's solar irrigation solutions, and also have an assured buyer in Claro paying fair market prices.

Technology and power electronics R&D

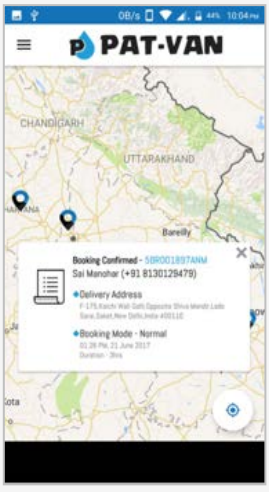
The project aimed at developing an IoT system that provided performance data. The IoT system would have a power electronics device that would be constant communication with a central command centre on a cloud architecture, record transactions dynamically as they happen on the ground and have a two-way communication that allowed the operator to change pricing or other parameters. A schematic of the architecture and associated hardware implementation is given below.

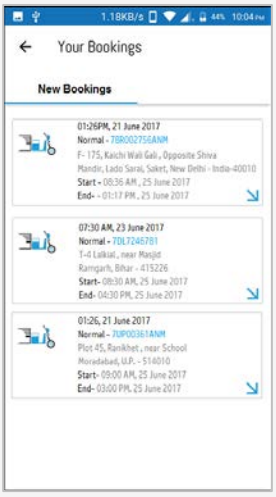


The challenge was to establish stable communication with cloud based technologies in the rural areas where the signals are spotty and unreliable and internet is usually not present.

However, the IoT system continued to face severe communication challenges. Between 2017 and 2018, India adopted 4G rapidly and the penetration of smart phones in rural areas also grew exponentially. Our architecture and much of the hardware was based on 2G connectivity. Many components of our IoT system failed to communicate and the sensors all needed to be upgraded. We did find success with different network technology such as Bluetooth for short range and LoRa (Low Power –Long Range) but those still required changes to network components and often did not work well with flow meter electronics. After discussion with experts, we decided to convert everything to mobile-based network architecture which the company expects to continue to develop in 2020.

Over the duration of the project, some key **software** technologies were also built using insights from this project. We developed an Android App for booking and scheduling irrigation service but farmers were reluctant to use the app. The reasons are network issues, and user comfort in calling to book service.





To facilitate the booking process, we used operators locally from the community. Farmers call these operators and book their irrigation. A PayGo card was issued to each farmer for identification and payment tracking. PayGo cards were designed and implemented to collect the service amount after each transaction. Each card had a unique number and was allocated to farmers individually. These cards were prepaid and could be topped up by the operators. The system was designed in such a manner so that the quantity of water consumed (measured through a flowmeter) was multiplied by a fixed unit rate. The final amount was thus automatically calculated and was paid by the farmers using the Paygo card.

We implemented the system at certain locations but it couldn't be continued due to lack of technology infrastructure implementation.

A digital payment feature to collect farmer payments through Pay-Tm (UPI payment) was also included. In the long run, the digital payment will provide transparency in payments but farmers are somewhat reluctant. In cases where we buy produce from farmers, this is acceptable now.

Results and summary

A total of 50 solar irrigation trolleys, 50 flexible systems, and 2 mini-grids have been deployed and services are carried out through three different business models, viz., pay-as-you-go, monthly lease and daily rental models. The irrigation systems impacted:

The farmers typically used the irrigation system for an average of 5-6 hours each day. Estimated earnings from the system is likely to be between 300 and 400 INR per day providing 50% savings over current irrigation method using diesel pump method.

The light weight flexible solar system shows a lot of promise from economic, ease of use and business model standpoints.

Product Solutions	Optimal Business Model	Preferred Sales Channel	Payback Period in Years	Comments
Solar Irrigation Trolley	Monthly rental	NGO, FPO, B2B	5 to 7	Trolleys are best utilized and they have under-utilized operator base to run the trolleys
Solar Irrigation using ultra-light solar panel	Daily rental	Local distributor	3 to 5	Local distributors provide agri-equipment on a rental basis and have relationship with farmers
Solar Irrigation using Mini-Grids*	Pay-as-you-Go	Direct	3 to 4	In partnership with mini-grid firms such as Husk Power and Tata Power, we provide irrigation as an anchor load and run irrigation service to farmers

* Irrigation demand is first created using PatVans and ultra-light systems

Other ancillary but related services such as the introduction of market linkage service to the farmers in which Claro gives assurance to buy produce from farmers seems to stabilize irrigation demand as well and increase adoption of clean energy systems.

Introducing third party other services such as facilitating, Agri inputs such as seeds and fertilizers, crop advisory, and financial services creates a holistic solution and supports the adoption of clean energy systems long term.

In summary, we have successfully demonstrated the business case for a clean energy service that is solar powered and provides crop irrigation to small and marginal farmers via a business model that can be scaled with capital infusion.

Progress on Project Milestones

#	Milestone	Means of verification	Due Date	Progress	Additional comments
01.a	M&E Plan	Electronic submission of documents to USAID, and sufficient incorporation of any revisions suggested by USAID	2016/01/12	Complete	
01.b	Work Plan	Electronic submission of documents to USAID, and sufficient incorporation of any revisions suggested by USAID	2016/01/12	Complete	
01.c	Business Needs Assessment	Electronic submission of documents to USAID, and sufficient incorporation of any revisions suggested by USAID	2016/01/12	Complete	
02.a	Participation in the Powering Agriculture Development Exchange in Washington DC to Showcase Project.	Electronic Submission of flight invoice and Powering Agriculture Innovator Showcase participant list	2015/11/30	Complete	
02.b	Community #1 Survey and site assessment completed	Electronic Submission of reports and photos to USAID containing the Community #1 survey, site assessment, details on the design criteria for trolley design, remote monitoring system, and scheduling system, including sufficient incorporation of any revisions suggested by USAID	2015/12/31	Complete	The assessment was completed in February but uploaded in May
02.c	Develop design criteria for trolley design, remote monitoring system, and scheduling system.	Electronic Submission of reports and photos to USAID containing the Community #1 survey, site assessment, details on the design criteria for trolley design, remote monitoring system, and scheduling system, including sufficient incorporation of any revisions suggested by USAID	2015/12/31	Complete	First designed externally which did not work and then had to re-design in house
03	Design and testing of trolley prototype, remote Monitoring System, and scheduling system.	Electronic Submission of reports and photos to USAID detailing the design and testing of the trolley, remote Monitoring and scheduling Systems	2016/03/31	Complete	The prototype was developed in house. Delays in hiring team and designing the prototype. Also, more design iterations than planned
04.a	Lab testing and Manufacture	Delivery to USAID of a Report detailing the operational performance of the 25 Systems during testing, including efforts to address challenges encountered	2016/06/30	Complete	Delays in search for a reliable local manufacturer. Ultimately trolleys manufactured in New Delhi and sent for deployment

#	Milestone	Means of verification	Due Date	Progress	Additional comments
04.b	Updated Work Plan	Work Plan submitted and sufficient incorporation of any revisions from USAID	2016/06/30	Complete	Same as 4a
05.a	Start of Community #1 systems and logistics center operations	Electronic Submission of reports and photos to USAID containing the Community #2 survey, site assessment, operational performance of the 25 Systems in the Community #1, details on the logistics center #1 operation, training, activities & Training materials, including efforts to address challenges encountered	2016/09/30	Complete	Delays cascading due to late design and manufacturing
05.b	Community #2 Surveys and site assessment completed.	Electronic Submission of reports and photos to USAID containing the Community #2 survey, site assessment, operational performance of the 25 Systems in the Community #1, details on the logistics center #1 operation, training, activities & Training materials, including efforts to address challenges encountered	2016/09/30	Complete	
06.a	Revise, test and manufacture trolley systems for community #2.	Delivery to USAID of a report and photos containing the operational performance of the 25 Systems for Community #2, including efforts to address challenges encountered	2016/12/31	Complete	
06.b	Community #3 surveys and site assessment completed	Delivery to USAID of a report and photos containing the Community #3 Survey, site assessment	2016/12/31	Complete	
06.c	Updated Work Plan	Work Plan submitted and sufficient incorporation of any revisions from USAID	2016/12/31	Complete	
07	Start of Community #2 Systems and logistics Center operations	Electronic Submission of reports and photos to USAID containing the operational performance of the 25 Systems on the logistics center #2 operation, training, activities & Training materials, including efforts to address challenges encountered	2018/10/25	Complete	Community #2 identified in 2017. Work on three communities commenced parallel due to strong interest. As the design changed, the available number of trolleys were distributed across communities

#	Milestone	Means of verification	Due Date	Progress	Additional comments
08.	Updated Work Plan	Work Plan submitted and sufficient incorporation of any revisions from USAID	2018/11/15	Complete	Plan updated to include three community operations in parallel
09	Evaluation of new Business cases & Review of design modifications	Electronic Submission of reports and photos to USAID containing the Business cases & needed design modifications, including incorporation of any revisions from USAID	2018/11/30	Complete	A new business models emerged: • Monthly Lease Model
10.a	Revise, test and manufacture trolley Systems for Community #3.	Delivery to USAID of a report and photos containing the operational performance of the 50 Systems for Community #3, including efforts to address challenges encountered	2019/01/30	Complete	A new irrigation service model emerged • Using mini-grids with irrigation pumps as anchor load
10.b	Updated Work Plan	Work Plan submitted and sufficient incorporation of any revisions from USAID	2019/01/30	Complete	
11.a	Start of Community #3 Systems and logistics Center operations	Electronic Submission of reports and photos to USAID containing details on the logistics center #3 operation, training activities & training materials, including efforts to address challenges encountered	2019/04/30	Complete	A new product form emerged: • Irrigation using Ultra-light weight solar panels
11.b	Evaluation of Scale Up & Commercialisation Plan	Electronic Submission of reports containing the scale and commercialisation plans review	2019/04/30	Complete	
11.c	Updated Work Plan	Work Plan submitted and sufficient incorporation of any revisions from USAID	2019/04/30	Complete	
12	Final Report	Submission of electronic documents to USAID, and sufficient incorporation of any revisions suggested by USAID	2019/06/15	Complete	The project was delayed by about 6 months due to changes in design, and implementation challenges

Lessons Learned

Claro Energy set out on a path to create a low-cost, on-demand, pay-as-you-go, solar powered portable irrigation service using solar panels and pumps mounted on battery-operated EVs serving small and marginal farmers in rural agrarian regions of North India. The idea was very well accepted by the rural communities however the whole process did undergo a lot of challenges which provided a path for the future course of action in terms of product, delivery service, areas of intervention, and economics. The lessons learnt are summarized as under:

Mechanical problems

- The solar irrigation trolley encountered several problems of stability, tilt of solar panels, support for heavy solar panels, wheel size, folding/unfolding system, and placement of pump among many. Trolley design went through several iterations to eventually converge to a stable manoeuvrable trolley on rural roads. *An external engineering and industrial design consultant early-on the project would have reduced number of iterations and overall time.*

Design

- In house design and implementation with specialized team may not always lead to desired results. A combination of external expertise and internal coordination is required when the complexity is high involving hardware and software technology, mechanical engineering and rural operations.
- Technology components need to be tested well in advance and for a good period after deployment to ensure that they work smoothly. For instance, our system was based on 2G spectrum that worked during test but quickly become obsolete when telecom networks shifted to 4G spectrum. Ultimately, IoT systems from the PatVans was discontinued in Feb 2018.

Technology

- Flowmeters that worked very well in the urban water supply industry were an expensive add on to the system and difficult to maintain in rural areas.
- Development of PayGo cards was a brilliant idea and an investment that was not very well accepted by the farmers who were apprehensive to use prepaid cards. This was not envisaged earlier and the could have worked on an alternative payment mechanism.

Team

- A well-established project team structure with a single point of accountability could not be maintained effectively often causing communication gaps and confusion on roles and accountability leading to milestone delays.
- Due to attrition, steps need to be taken to ensure an overlap period between the outgoing team and the new comers.
- EV-battery problems were due to lack of personnel experience in procurement. Later that was resolved by changing vendor and enforcing warranty.

Gender Integration

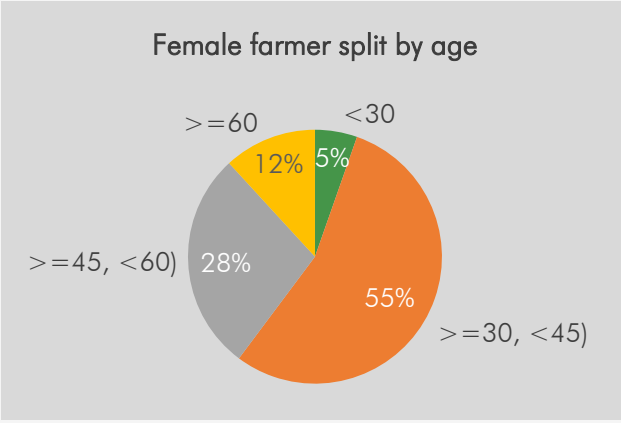
Women comprise the vast majority of smallholder farmers and food producers and participate in all aspects of rural life. Women are more likely to reinvest their income back into their families to improve education, nutrition and health. As per USAID, "Women farmers are not as productive as men due to less access to land, markets, farming technologies, fertilizer, credit and training. That's a lot of untapped potential". Claro Energy, as part of PAEGC project, is working in rural areas among farming communities on gender equality promoting solar powered irrigation services and empowering women with more profitable agriculture.

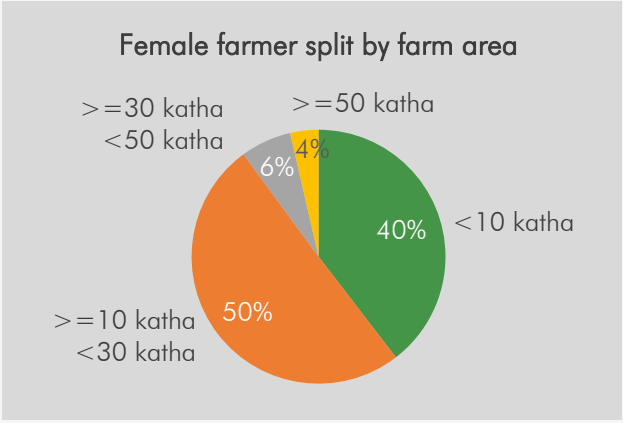
Baseline survey

A baseline survey in the community helped create women farmer groups based on two key demographic information:

- *Income level* – The focus was placed on low income women farmers to provide them awareness about cost effective irrigation model and better agricultural practices to have higher adoption of PatVans.
- *Type of crop* – Women growing a particular crop were further grouped together to provide them with crop-specific training or knowledge.

Demographic information of women farmers is given below:





Formation of women farmer groups

Women farmer groups were formed with the help of rural on the ground non-government organizations (NGOs). Creating women farmer groups allowed the solar irrigation innovation information to reach to many women and men farmers in a community very quickly and facilitated discussions within themselves and with our teams in a convenient manner.

The NGO organizations that Claro worked closely with are listed in the table.

Sehgal Foundation	Create sustainable programs for managing water resources, increasing agricultural productivity, and strengthening rural governance.
Kaushalya Foundation	Aims at achieving socio-economic empowerment of the poor and underprivileged as well as developing youth.
Vaishali Area Small Farmers Association (VASFA)	Focuses on awareness creation among farmers and women empowerment.
Jan Nirman Kendra	A local NGO working for society welfare in the areas of agriculture and education.
Transforming Rural India TRI	TRI supports NGOs working at the grassroots, to move towards achieving the common goals to transform rural India.
Sumeena Foundation	A local NGO with a focus on rural development through awareness creation and grass root level demonstrations.

Training for women farmers

The dedicated training programs jointly conducted with local NGOs helped women farmers overcome their inhibitions about the new technology. Separate women trainings in a closed group allowed women attendees to talk freely. In the presence of male members there is a tendency to feel shy and not open up. Women in the communities where we operated are not socially encouraged to do farming nor are they involved in major economic decision making. Training and demonstration program for women farmers equipped them with knowledge to generate more profit from the land and brought them to the front in the village. Women encouraged more women in the village. Many women farmers now come for solar irrigation.

Incentives for Women Farmers for using Solar Irrigation

Claro Energy also promoted the irrigation services by incentivizing women farmers to adopt sustainable clean energy solutions. Some initiatives are listed below:

Priority on irrigation through PatVan – Women farmers were given irrigation priority and PatVans were made available and accessible while other farmers operated on a first come first serve basis. Women farmers feedback on the flexibility was quite positive.

Financial incentive – Women farmers received a discount was offered on each usage and the women farmer using maximum service in a month was awarded with one free irrigation service for land up to 10 kattha (0.003 acres).

Operational support – For women farmers, Claro solar trolley operators helped with taking the flexible pipeline to the field, folding and unfolding of the pipes, and other labour intensive tasks associated with solar irrigation trolley.

Role of PAEGC Funding and associated support

PAEGC funding has been critical to understanding irrigation needs of rural farmers and developing product and business model solutions that are low-cost, effective, and have mass appeal. PAEGC funding allowed us to have multiple failures (learnings) on the ground, iterate, rapidly prototype and put a reformed solution on the ground. The funding also allowed us to explore the design space more extensively and come up with newer business models (other than only PayGo) and more product forms (irrigation system ultra-light flexible solar panels system and irrigation service via mini-grids) that fit the needs of segment of customer quite well. PAEGC funding has allowed us to evaluate best sales channels for different product forms. If the PAEGC funding was not available, one would not have been able to learn about the breadth of irrigation solutions for small and marginal farmers in a manner that Claro Energy has been able to.

PAX support was crucial to building a methodical approach to product development and testing. PAX trainings and sessions helped uplift the learning and knowledge level of engineers and managers on the field, and improved the overall quality of the clean energy solution.

Claro Energy has raised a total capital of USD $4,000,000 since the start of PAEGC project. As part its scale up plan, the company is raising additional capital to manufacture the product solutions and sell via sales channels.

Acknowledgment

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Future Plans

The various activities in the villages of Bihar proved that the solar irrigation system has latent demand in the village that can be unlocked.

Based on the lessons learnt on field with the solar irrigation trolley, a portable solar irrigation model which used flexible solar panels was developed towards the end of the project. The ultra-light solar irrigation system had more operational flexibility and better economics. A future goal will be to refine the design of this system further and make it easy to be used as a plug and play system. The system will be available in different sizes to cater to the needs of small and marginal farmers.

Challenges associated with mechanical problems of the trolley have largely been resolved. Minor trolley modifications will continue to improve stability and robustness.

Another area of further work will to be re-haul the IoT system that faced communication challenges with the cloud and with flowmeter electronics and could not record accurate and timely data needed for on-the-spot transactions. Technology and communication associated challenges are being developed in the next version of the IoT technology release.

The experience working with farmers across various geographies providing them with water for irrigation, we learnt that the farmers were largely unable to realize fair prices due to lack of awareness, monopoly of the local middleman, lack of other credible buyers of produce. As an extension of irrigation services, Claro provided 'market linkage' to farmers to purchase the produce at fair market prices. Coupled with irrigation services at the time of growing, the produce purchase service complemented the offering very well and stabilized the irrigation demand as well.

The company plans to raise external funding to build and deploy more mobile solar trolley and ultra-light irrigation systems and expand the reach of its solution to 50,000 small and marginal farmers in India and Africa.

Annex A: Performance Indicators Table

Indicator	Value/ Answer	Units	Comments, Data Source, Calculation
IR 1: Increase in Farmers and Agribusinesses' access to and/or use of clean energy solutions			
1.1 Type and # of CES developed	4	Nos.	
State of CES Development (choose one): a. Concept Development b. Research and Development c. Initial Piloting d. Early Adoption/Distribution e. Market Growth f. Wide-scale Adoption	Early Adoption/ Distribution		
# of CES units deployed	100	Nos.	
1.2 # of beneficiaries with improved energy services	997	Nos.	Total number of farmers registered is 1563. 566 farmers were added when a project audit was done in fall of 2019
Type of beneficiaries: (i.e., dairy farm, processing facility, other commercial customers, residential customers)	Residential customer		
# of beneficiaries that are female	326	Nos.	
Location of farm	Bihar		
Size of farms (as defined by area)	<1	Ha.	Small holder farmers
Size of farms (as defined by financial revenue in USD, based on estimations by farmer)			
1.3 # of wholesalers/retailers/maintenance professionals accessible to beneficiaries for selling/servicing CES	21	Nos.	
# of professionals that are female	2	Nos.	Located in New Delhi
Location	Bihar		
New or existing (since PAEGC implementation began)	21	Nos.	
1.4 Clean energy generation capacity installed	0.199	MW	50 flexible irrigation system with 1920wp each & 50 trolleys
1.5 # of persons attending trainings/ demonstrations on CES technology	1,922	Nos.	
# of persons that are female	503	Nos.	
Type of event (choose one) a. Demonstration b. Training session	Training Session & demonstration both		

Indicator	Value/ Answer	Units	Comments, Data Source, Calculation
IR 2: Increase in agricultural productivity and/or value among farmers			
2.1 Change in agriculture production attributed to use of CES Baseline value is required – quantity produced before project was implemented. "Change" can be in volume, quantity, weight or reduction in loss. Need to specify unit of measurement, and with what periodicity. Include a) value per household and b) total change in agricultural activity among all users.	120	Kg/acre	Increase in agriculture farmers grown the similar crop as of last year 120kg/acer is the total value for FY 18 and FY 19
2.2 Change in income attributed to use of CES			
Agricultural good from which net income is derived	3842	US$	Due to increase of productivity & saving fuel consumption, this helps to increase farmer income
2.3 Expected life of project savings from energy conservation (during reporting period) Asks for energy savings as compared to receiving the same services with a fossil fuel technology; as a result of an energy efficient technology; or due to behavioral changes of the users.	0	KWh	The total energy to pump a unit quantity of water is same between the two sources of energy (diesel or solar). The farmers used diesel pumps before
IR 3: Increase in support for low carbon economic growth within the agriculture sector			
3.1 Amount of mobilized USD from private and public sources for climate change	4,000,000	USD	
Amount of mobilized USD from public investors in addition to PAEGC		USD	
Amount of mobilized USD from private investors	4,000,000	USD	
3.2 GHG emissions reduced as a result of CES (during reporting period) Use the CLEER Web Tool at https://www.cleertool.org/	144.9	Tons	

Annex B: Environmental Monitoring and Mitigation Plan (EMMP) Progress

Include the EMMP progress table below to summarize all mitigation measures undertaken on the project and any outstanding issues remaining at the end of the project.

Activity / Impact	Summary of Mitigation Measures Undertaken	Outstanding Issues Related to Required Mitigation Measures
0) Properly dispose of batteries	The mobile solar trolleys were battery operated. Battery disposals were done per manufacturer's protocol. In all cases when batteries malfunctioned, they were returned to the manufacturer for disposal	Develop standard internal operating procedures and follow up trainings that ensure that used PatVan batteries are properly disposed of
1.a) Limit over pumping by limiting the size of the solar pumping system installed	All pumps deployed in the communities were of sizes less than 2 kW	None
1.b) Monitor amount of water delivered in the fields using remote monitoring system and a flow meter to assess underground water withdrawal	Water monitoring was done initially. However, since the flow meter and IoT electronics did not work well, we were unable to measure water discharge data	Develop an estimate of water discharged based on time of use which is to be calculated through data in operator log book or revenues collected
2.a) Recycling solar panels using manufacturers recycle plan	Measure power output at the end of 25 years to assess whether to continue or send back to manufacturer for recycle	None
2.b) Replace any broken panels. Return broken panels back to manufacturer	Isolate broken panels in warehouse and follow replacement or disposal of solar panels as per manufacturer's instructions	Training of operational personnel on manufacturer's protocol
2.c) Replace drives and pumps	Plan in place via supplier replacement and warranty program	None
2.d) Send wirings and metal scrapings to local firms which recycle scrap metal	There is very little wiring and scrapings waste if any. In general, wiring and metal scrapings are sent for recycle through existing recycle channels	None

About Claro Energy

Claro Energy is considered a Solar Pumping Technology pioneer and is credit with engineering India's first modern solar pump in 2011 which spawned the solar pump industry. Today Claro Energy employees 130 people, has operations in 15 states of India, has deployed 10,000 solar powered irrigation pumps that save 7.5 million litres of diesel and 20,000 T of CO_2 emissions each year, and has helped thousands of farmers come out of poverty. The company has received numerous awards and recognitions including winning 2017 Asia Entrepreneurship Award and 2015 Powering Agriculture Grand Energy Challenge.

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