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The Benefits of Solar Technology Adoption for Street Vendors in Bihar: **Final Report**

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1 Introduction

Energy poverty is often considered a rural problem, but the urban poor of developing countries also suffer from limited energy access. According to the 2013 *World Energy Outlook* of the International Energy Agency (IEA, 2013), the household electrification rate in urban areas of developing countries is 91%. In most of these areas, however, the supply of electricity is intermittent and extreme voltage fluctuations damage equipment. Furthermore, the household electrification rate omits access to electricity in the informal enterprise sector. Because of rapid urbanization in developing countries (Montgomery, 2008), urban energy poverty is a significant contemporary problem. People living in slums work in the informal economy without secure property rights or access to basic infrastructure services (Agarwala, 2013). Improved access to electricity can contribute to enhanced livelihoods for the urban poor.

This report summarizes our experience with an impact evaluation of an intervention to provide street vendors with improved lighting through solar power in Patna, the capital of the state of Bihar, India. In the project, a local non-governmental organization, Nidan, targeted street vendors in Patna's marketplaces. In the targeted marketplaces, Nidan and a technology provider, PowerGreen Renewables, set up a centralized charging station with the capacity to offer up to 24 street vendors with a 5-watt light for use at night. The vendors could subscribe to the service in exchange for a daily fee of 10-15 rupees. The intervention was evaluated with the help of baseline, midline, and endline surveys both in the targeted and control markets. The choice of markets was randomized to enable a proper impact evaluation.

The result of the intervention was negative. Because of difficulties in implementation, Nidan did not reach the targeted number of vendors. In market places with centralized charging stations, Nidan then faced technical and management difficulties that resulted in a decrease in the number of vendors using thee lights. The surveys demonstrate that Nidan was able to reach a large number of vendors, but the techno-economic model did not prove viable in the end. Because Nidan was unable to deploy a large number of lights in the field and support their use over time, the intervention did not generate the socio-economic benefits that Nidan was hoping to see.

The project offers a number of useful lessons for future interventions to offer electricity access to the urban poor. To begein with, the urban market setting has a much more complicated socio-economic logic than the typical rural community, where centralized charging stations are now frequently operated by non-governmental organizations and private companies even in Bihar. Urban marketplaces have highly developed, if informal, systems of governance revolving around the local strongmen. The strongmen operate diesel generators and perceive solar stations as a threat to their business, complicating installation and raising barriers to a successful intervention. The strongmen are not interested in replacing diesel generators with solar stations because the former provide a steady and reliable source of revenue, whereas the latter is a new technology that offers only an incremental improvement over the diesel generator. Moreover,r the rental model creates problems because vendors have little incentive to use the lights properly. Finding local entrepreneurs is difficult and the compensation required increases the cost of solar lighting to a high level. Physical barriers, such as land availability, are also an issue.

2 Project Details

The project partners were an Indian NGO, Nidan, and a Patna-based renewable technology provided, PowerGreen Renewables. Nidan operates across a large number of cities in India and emphasizes the livelihoods of people working in the informal sector, such as street vendors. Nidan was a collaborator from the beginning, whereas PowerGreen Renewables was chosen during the project based on a review of possible technology suppliers. The major asset of PowerGreen Renewables was that their operations were based in Patna, so we could rely on continuous technical support during the project.

Each centralized charging station is designed to provide a lighting solution for 15-20 vendors. The solar technology used in the project can be summarized as follows:

- 150-watt solar photovoltaic panel for the centralized charging station
- 5-watt light for each vendor
- Tubular lead acid battery for each vendor.

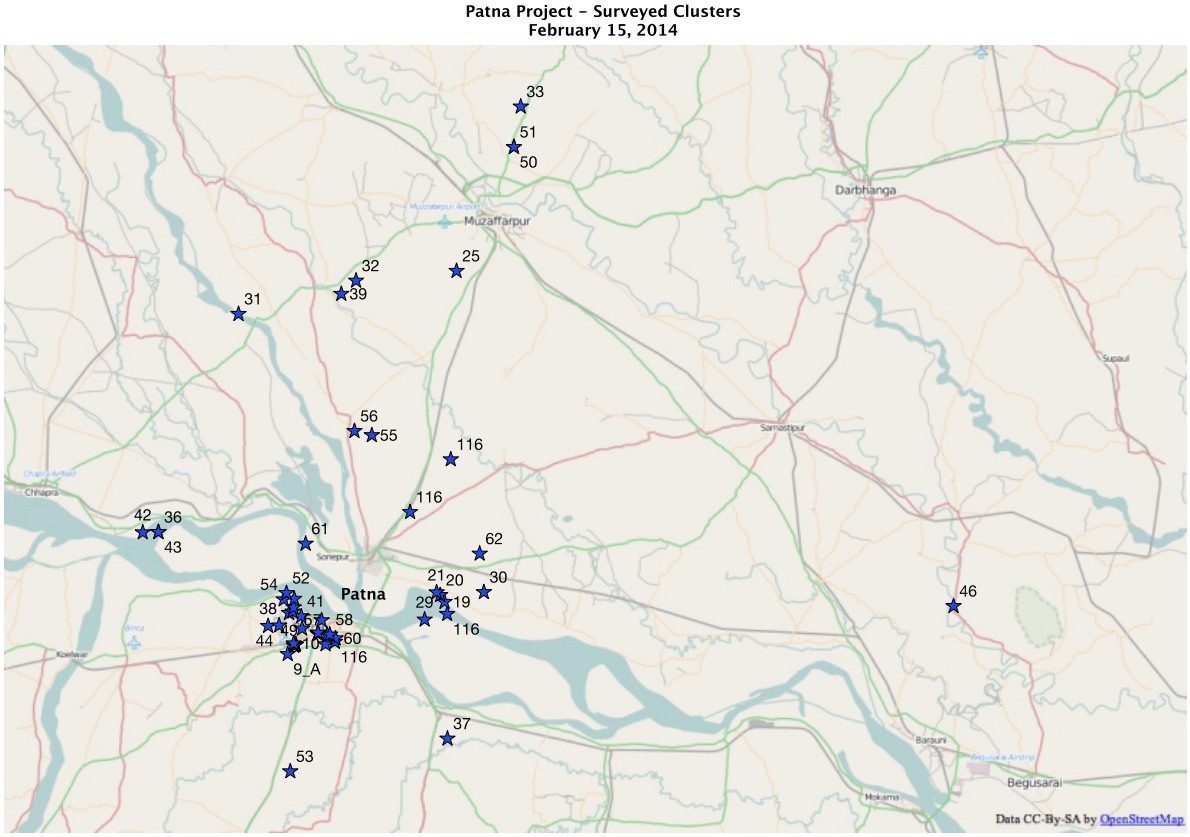
For the solution, vendors were typically required to pay 15 rupees per day. From this payment, 6 rupees went to PowerGreen and the rest to Nidan. PowerGreen agreed to provide a warranty and maintenance guarantee for the duration of the project.

The marketplaces were chosen as follows. First, Nidan submitted a list of more than 50 marketplaces in the Patna urban area, including the nearby satellite city of Hajipur. Second, Nidan went through the list and excluded marketplaces that were too small (30 or fewer vendors), presented obvious security or safety considerations, or were undergoing construction. Based on these exclusions, we were left with a list of 24 marketplaces. The Nidan team then visited all marketplaces and verified that a centralized charging station could be constructed at least in principle.

Because each centralized charging system provided electricity for between 15 and 20 vendors at any time, randomizing which vendors would receive access could not be done at the individual level. That is, we decided that selecting vendors to receive the subsidized lights within a marketplace would potentially result in spillover effects and undermine the independence assumptions require to conduct the randomized control trial. However, the sample 24 named marketplaces in the urban areas of Patna did not provide enough statistical power to randomize at the true marketplace level. To solve this problem, together with NIDAN and Morsel, we identified natural boundaries within each marketplace that delineated small clusters of vendors.

In all, we were able to create a list of 59 clusters spanning the 24 marketplaces. We randomly assigned each cluster to the treatment group (would receive centralized charging system) and the control group. Then after choosing one marketplaces with two clusters as our pilot location, we randomly ordered the remaining treated clusters. NIDAN would then follow this order in choosing when each cluster would be approached for demonstration and installation. Local entrepreneurs were to be found in each cluster to oversee the management of the centralized system along with NIDAN. These individuals would be responsible for collecting the daily payments from vendors for weekly collection by NIDAN. In addition, they would work together with NIDAN to arrange for repairs needed to the lights to be paid for by a separate maintenance fund. When setting the prices for the light and battery rentals, 2-3 extra rupees were added to the baseline price to adequately compensate this entrepreneur for their efforts.

Figure 1: Cluster Map



3 Data Collection

The data were collected in three surveys of the 24 marketplaces. The baseline of 1,000 vendors was conducted in January-February 2014, before the implementation of the intervention. The follow-up surveys were implemented in May 2015 and September 2015. Initially, the follow-up surveys were supposed to be conducted already earlier, but delays in the implementation of the project forced us to delay the surveys. Because the intervention continued until the end of the calendar year 2014, May 2015 was the earliest possible time for the midline. The endline, on the other hand, was implemented in September 2015 to ensure we could analyze the data before the end of the grant period on October 31, 2015.

The surveys were conducted by MORSEL India, an experienced private company that has carried out similar projects throughout India. Each interview lasted approximately 45 minutes and was conducted in Hindi, a language that all vendors spoke, by experienced enumerators who were fluent in the language. Compensation of INR 10 ($USD 0.16) was paid to the vendors in exchange for their participation. The average response rate across the three surveys above 90%, as is typical in the Indian context. Nidan staff members assisted the survey enumerators in gaining permission from the local leaders to conduct the surveys in the marketplaces.

In the midline and endline, we tried to survey the same respondents surveyed in the baseline. Overall, we were able to survey 622 of the baseline respondents at least twice. Attrition resulted from migration, seasonal labor, and changes in the marketplaces themselves. Each of the surveys included between 10 and 12 modules about vendors demographics, business characteristics, electricity needs, assessments of the business environment, social relations, political behavior, and other behavioral traits. We also analyzed placed several questions on the baseline survey to assess vendors' willingness to pay for rented solar lights on a daily basis, which we used to derive the final price to be offered during installation.

Throughout the project implementation, we also deployed a monitor to ensure that we were aware of the progress of the intervention. The monitor was hired, trained, and managed by MORSEL in the field to give us oversight over NIDAN. Each day the monitor travelled to two marketplace clusters, logging any problems that vendors were having with their lights, as well as attended the demonstrations, installations and distributions completed by NIDAN.

4 Results

4.1 Energy Poverty among Street Vendors

Before beginning the intervention, we investigated patterns of energy poverty among the vendors. Before investigating energy issues in particular, we note that the population overall is highly marginalized. Only 64% of the vendors could read Hindi, even though they are all involved in operating a business. Moreover, 67% of the respondents reported being in the business because they felt they had no choice and 40% reported being in debt.

The analysis of the 1,000 baseline respondents also confirmed that the population suffered from high levels of energy poverty. The average daily cost of lighting was 10.6 rupees among those who paid for their lighting, with some vendors paying as much as 50 rupees per day. Still, on average vendors reported only having 3.6 hours of artificial lighting per day on average. Given that the sun typically sets in Patna around 6 PM, this means that there was not enough light to operate until 10 PM. Among the vendors, 11% said they depended on candles and 13% reported not having their

own lighting at all. 27% used a chargeable battery light and only 11% reported using kerosene, LPG, or emergency lights. Only 10% of all vendors had a grid connection, and among them only four in ten had a legal connection. 26% of the vendors were currently reliant on monthly fees for a diesel generator.

The survey also revealed that the vendors considered improved lighting a top priority. When asked about the importance of lighting, 80% said it was their top priority. At the same time, 88% of the vendors believed that improved lighting would allow them to attract more customers at night and 86% believed that they could work longer hours with improved lighting. These numbers testify to the need for a lighting intervention.

4.2 Centralized Approach

Installation of the centralized systems began in March 2014, two months after the completion of the baseline survey. We began our efforts in the Hartali Mod marketplace where a product demonstration of the solar system was held in late March 2014. A local female vendor signed up to be the entrepreneur, twenty vendors expressed interest in renting access at a rate of seven rupees per day, and a location to install the system nearby the marketplace cluster was quickly identified. Within two weeks of the initial entry to the marketplace, these twenty vendors were illuminating their stands at night with the solar-powered lights. The following month we moved onto the nearby Rajendra Nagar marketplace, which is approximately six times larger than the Hartali Mod cluster. Over the course of the next five weeks, we were able to successfully install an additional seven centralized panels to provide solar lights for 120 vendors. Two entrepreneurs were found to manage these systems, working in close cooperation with our local partner to collect payments and provide maintenance assistance. In sum, in the spring of 2014, we provided access to lighting for no fewer than 140 individual vendors.

The status of the marketplaces approached after six months of implementation is summarized in Table 1. It shows that Nidan succeeded in implementation in three marketplaces. In six marketplaces, repeated efforts did not result in successful installation. In one marketplace, installation succeeded initially but Nidan had to withdraw because the local entrepreneur did not manage the system and business well. The success of the implementation, as measured by vendor approach and adoption rates is presented in Table 2. We were able to offer access to solar power from the centralized charging systems to nearly 21% of all the vendors which were surveyed in both the baseline and midline surveys, or 117 individuals. Of these, only twelve vendors surveyed agreed to rent the systems, giving us an adoption rate of roughly 10%. Knowing that the centralized systems actually provided solar electricity to 140 vendors over this period, a true extrapolation of the 10% adoption rate would mean that we approached roughly 1,400 vendors across the markets. However, seeing that attempts to install and hold demonstrations were only held in nine markets with a total population of no more than 1,260 vendors, we conservatively estimate that the rental model was offered to no less than 600 vendors across the markets. Because of implementation problems below, systems were only finally installed in three marketplaces.

The process of installing the centralized systems more widely ran into a series of obstacles to implementation. Based on our initial discussions with the local partner, analysis of previous project and original baseline survey analysis, we were confident that not only was the lack of lighting a persistent problem in the marketplaces, but that few solutions were available to vendors. As we rolled out the design, this turned out to be only partly true. Although vendors had complained widely about difficulties securing access to power, there were diesel generators available to buy

Figure 2: Lights Deployed at Hartali Mod Marketplace

Table 1: Status of Lights Deployed

Marketplace	Fuel Exp. (daily, INR)	Vendors	Feasibility	Comments
Success				
Hartali Mod	14.7	50	Yes	System running without major problems, vendors pay INR 15 per day
New Sachiwalay	6.88	60	Yes	Some vendor complaints about quality of lighting, vendors pay INR 15 per day
Rajendra Nagar	7.37	500	Yes	System running without major problems but many areas of this large marketplace remain with service because of land availability and threats made by local strongmen, vendors pay INR 15 per day
Failure				
Asiyana	9.97	60	Not Possible	Nidan could not find an entrepreneur and local strongmen started to express concerns about the project during the marketing campaign
Chitkora	11.7	220	Not Possible	Local strongmen were against the project
Jagdev Path	12.5	120	Not Possible	Nidan could not find an entrepreneur and local strongmen started to express concerns about the project during the marketing campaign
Khagol	7.76	80	Not Possible	Local strongmen were against the project
Malahi Pakadi	7.85	20	Not Possible	Nidan could not find an entrepreneur
Punai Chak	8.54	40	Not Possible	Local strongmen were against the project
Withdrawal of System				
Gaya Line Gumti	7.6	110	System Failed	Entrepreneur mishandled the system and refused to make payments to Nidan

Table 2: Solar Adoption: Rental and Standalong Models

	Rental Model	Standalone Model
Vendors Approached	117	246
Approach Rate	20.5%	39.6%
Vendors Adopting Solar	12	10
Adoption Rate	10.3%	4.1%
Total Vendors in Baseline and Midline	572	
Total Vendors in Baseline and Endline		622

electricity from in the majority of marketplaces. The cost of daily use of these generators was prohibitively high for most sellers, but this lack of demand did not prevent the generator operators from conducting this business. Instead, the owners of the generators acted as local strongmen who were involved in managing vendor relations and local disputes with local officials. These strongmen viewed the installation of a centralized solar system as direct competition to their generator business and actively worked to impede the efforts of our local partner.

Attempts to convince the generator operators to switch over to the solar model also proved futile. Though overall these local operators were skeptical about the benefits of new technology, they also had invested considerable resources into installing wiring infrastructure for their own generators. Our proposals to retrofit their set-up to accommodate solar panels and to generously subsidize the costs of doing so were considered, but ultimately rejected since several individuals did not see a clear, unambiguous advantage of solar technology to their own. These strongmen also took steps to prevent vendors from cooperating with us by signing up as the individual entrepreneur to oversee the system. The baseline and feasibility studies we conducted prior to implementation did not uncover the extent to which marketplaces were dominated by strongmen hostile to the solar concept. The obstacles presented by these strongmen, paired with physical barriers of identifying suitable locations to install the systems in heavily trafficked marketplaces, inhibited project implementation.

Another key problem with the centralized system concerned vendor interest and behavior. Educating vendors about the advantages of solar batteries for their business proved more difficult than anticipated. Often several demonstrations were necessary to prove the durability of the devices, which were perceived as foreign to shopkeepers accustomed to using car batteries or candles for light. Others were interested in the concept, but even the nominal price of the rental caused them to prefer ambient sources of light, such as from street lamps. Moreover, a moral hazard problem arose among those that agreed to rent the lights. Initially we opted for the rental model by which vendors could make small daily payments for battery usage because of concerns about their up-front ability to afford any larger investment in solar technology. Unfortunately, the small amount of payment and a non-contractual obligation to participate in the long-term project reduced any interest vendors had in properly maintaining the devices. Our design assigned responsibility to the individual entrepreneur, local partner, and supplier for maintaining the lights, giving little incentive to the vendors to treat the devices with respect.

4.3 Standalone Approach

In July 2014, we conducted a preliminary evaluation of the rental-based centralized hub approach. We discussed the weaknesses of the project's strategy with the program manager and regional director of our local partner, marketplace leaders, our supplier, and fourteen street vendors located both in marketplaces where we had attempted to install the systems and in those where plans to do so were underway. Over the course of these interviews, we determined that to successfully install additional centralized system in new marketplaces would require far more time than we were prepared to commit. Moreover, given the difficulties of maintaining the systems, we were unsure about the continued financial sustainability of the model.

The team then began to assess other options to deploy the lights. The most promising of the set of plans that was developed was to exchange the centralized solar panels for individual panels that could be connected to the lights and batteries. All of the equipment could then be organized into a stand-alone package to be sold at a subsidized price to the vendors. The advantages of this approach were multiple. First the sales model eliminated the need to identify and train a local entrepreneur to manage the centralized system, collect payments, and implement repairs. Instead, each vendor would take ownership over their own solar system, creating aligned incentives to keep the lights operational next. In addition, the sales model would allow our local partner to distribute the lights more quickly to the end-users since land and other arrangements were not necessary to sell the individual systems. Following several discussions, the investigators and the partners agreed that to continue maintaining those centralized systems already installed in marketplaces, but to switch over immediately to the sales model for distribution.

We then negotiated a deal with the supplier to exchange the large panels for small ones as well as for the assembly of the stand-alone systems. Marketing materials were also prepared that communicated to vendors the advantages of solar lighting. In order to preserve randomization within the research design, we decided that vendors would be randomly assigned whether they would receive the opportunity to buy the stand-alone system at a discount. At the beginning of each week, representatives from the local partner would enter a marketplace and educate the vendors about the solar systems using the promotional materials. They would also arrange a demonstration of the system and invite vendors who attended to enter into a free lottery to win a chance to buy the system at the price of 1999 rupees. Where possible, vendors that had participated in the baseline survey were prioritized in being invited to attend the demonstration. The local partner would then would return to the marketplace several days later with the systems available for purchase. Vendors would be offered an installment plan by which they could pay off over a period of time. We narrowed the list of marketplaces in which we would conduct the lotteries since randomization in the new standalone design would take place at the individual level, and not at the cluster level as under the centralized approach.

Over the next six months, we were able to conduct demonstrations and sell the solar lights in eleven marketplaces around Patna. 187 vendors from these marketplaces entered the lotteries that were held, which produced 99 randomly assigned winners to receive the opportunity to purchase the solar light at the subsidized price. Of these 99, 21 vendors chose to buy the lights, at a price of 1999 rupees per solar lamp. Unfortunately, this small number of successful purchases does not allow us to run statistical analysis to measure the effect of the solar lamps on vendor behavior. As seen in Table 2, we were able to offer the purchase of the standalone model to 246 vendors who were surveyed in both the baseline and endline surveys, of whom 10 actually purchased the lights (roughly half of the 21 vendors that we knew purchased the lights, or an adoption rate of 50%).

Extrapolating from these figures indicates that no less than 500 vendors entered the lotteries for the discounted systems, but too few actually purchased them in order to measure the effect of the project. Several factors explain the low level of demand for purchasing the lights. First, even with the generous subsidy and the installment plan, only a small number of vendors could afford to pay the full amount for the lamp. Secondly, the quality of lamps was inferior to only slightly more expensive conventional systems, such as those running on rechargeable car batteries. The weak strength of the solar lamp did not make it a convincing alternative to other projects on the market.

5 Conclusion

The intervention failed because of problems with implementation in the context of urban markets in Patna. Although the baseline survey revealed a clear problem of inadequate lighting, neither the centralized charging station nor the standalone model were able to generate a viable, effective business model. Technology adoption was not widespread enough to generate the socio-economic benefits expected.

This study highlights the challenges that policymakers face in implementing problems to solve urban energy poverty. The urban setting has a much more complicated socio-economic logic than the typical rural community, where centralized charging stations are now frequently operated by non-governmental organizations and private companies even in Bihar. Urban marketplaces have highly developed, if informal, systems of governance that revolved around local strongmen. These strongmen operate diesel generators and perceive solar stations as a threat to their business. These strongmen are essentially the vested interests who worry about competition from centralized charging station, complicating installation and raising barriers to a successful intervention. The strongmen are not interested in replacing diesel generators with solar stations because the former provide a steady and reliable source of revenue, whereas the latter is a new technology that offers only an incremental improvement over the diesel generator. The rental model creates problems because vendors have little incentive to use the lights properly. Finding local entrepreneurs is difficult and the compensation required increases the cost of solar lighting to a high level. Physical barriers, such as land availability, are also an issue.

Our results cast doubt on predictions from Yaqoot, Diwan, and Kandpal (2014), who use *ex ante* survey analysis to evaluate the feasibility of centralized charging stations. Our intervention appeared feasible on paper, the realities of actual implementation proved to be quite different. *Ex ante* feasibility studies cannot adequately capture the major difficulties associated with setting up centralized charging stations in the densely populated and often chaotic urban marketplaces in the developing world. The lack of clear property rights, contract enforcement, and legal protection in cities such as Patna have created deeply institutionalized urban communities that have their own rules and customs. Because the centralized charging station model depends on community acceptance, implementation is difficult in the urban setting. Unless the economic value of solar technology improves so much that solar lighting becomes an unambiguously superior alternative to diesel generators, these barriers to use in urban marketplaces are likely to remain in place. In general, results from rural interventions cannot provide reliable guidance for urban interventions due to major differences in the context.

Of course, some of the problems faced can be ascribed to project design. A revised project plan could, for example, specifically target areas with few diesel generators, invest more heavily into training entrepreneurs, and use more robust solar devices. All these improvements could improve

the chances of future interventions. However, it is important to note that all these revisions would again increase the project cost, making cost recovery even more important. Although the project design may not have been ideal, possible improvements to it would increase the project expenses above the grant subsidy given to the current project.

What can policymakers learn from this intervention to help design future interventions that avoid these pitfalls? One alternative for policymakers to consider would be to simply focus on grid extension or street lights. Cities such as Patna have electricity grids and the cost of providing connections to street vendors would not be too high since most marketplaces are not remote. This approach requires a coordinated approach by the municipal corporation based on the idea that street vendors should be provided with proper infrastructure. Since existing literature suggests that municipal corporations sometimes consider vendors a nuisance to be removed (Cross, 1998), a change of attitude is required for this approach to work. Indeed, India's 2014 Street Vendors (Protection of Livelihood and Regulation of Street Vending) Act provides a promising legal basis for concrete action to legalize and regularize the livelihoods of street vendors in urban areas. A collaborative effort between an NGO such as Nidan, a technology provider such as PowerGreen, and the municipal corporation could provide street vendors and other workers in the informal economy with basic lighting access, improving livelihoods and contributing to urban socio-economic development. An important challenge for the grid extension approach is the possibility of scheduled load shedding or unannounced power outages at nights, because this is a peak time for power consumption in urban India. If grid connections were combined with storage capacity, as would be true of a battery-charged light similar to the ones provided by PowerGreen, this obstacle might be overcome.

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