

Springer Copyright Notice

Copyright (c) 2019 Springer. Personal use of this material is permitted. Permission from Springer must be obtained for all other uses, in any current or future media, including reprinting/republishing this material for advertising or promotional purposes, creating new collective works, for resale or redistribution to servers or lists, or reuse of any copyrighted component of this work in other works.

The file is a pre-print of the publication.

Published in: Research into Design for a Connected World. Smart Innovation, Systems and Technologies, vol 134

DOI: 10.1007/978-981-13-5974-3_39

Published at: https://doi.org/10.1007/978-981-13-5974-3_39

Cite as:

Nair S. et al. (2019) Design of a Do-It-Yourself (DIY) Based Solar-Powered LED Lighting System for Training and Empowering Rural Youth. In: Chakrabarti A. (eds) Research into Design for a Connected World. Smart Innovation, Systems and Technologies, vol 134. Springer, Singapore

Design of a Do-It-Yourself (DIY) based Solar Powered LED Lighting System for Training and Empowering Rural youth

Abstract. Do-It-Yourself (DIY) approach is an effective pedagogy method for providing learning experience to the user. The DIY approach also gives a sense of ownership (and empowerment) to the people as they assemble the product themselves. It also provides a vocational training platform for innovative ideas of people by extending the applicability and its realization.

The design of 'Roshini', a DIY model for solar powered reliable lighting system aims at improving the adoption of improved sanitation practices, and sensitizing the community, through the youth, on good hygiene practices. Roshini also addresses the issue of lack of safe, well-lit sanitation access, lack of power supply for mobile phone charging and other basic daily needs which require electricity.

The paper discusses the design approach towards the proposed development of 'Roshini' – A DIY based solar powered LED lighting system.

Keywords: Do-It-Yourself · Sanitation · Photovoltaics · Rural youth empowerment · Pedagogy.

1 Introduction

Access to safe and adequate sanitation is fundamental to the well-being and prosperity of individuals. But in 2015, 2.3 billion people across the globe lacked access to even basic sanitation, of which 892 million people practiced open defecation, 90% of which lived in rural areas [1]. As per Census 2011, 69% of rural households in India had no latrine facility within the house [2]. Successive governments have made several efforts directed at ensuring total sanitation in the country through campaigns and policies like Total Sanitation Campaign (1999) and Swachh Bharat Mission (2014). India has been able to reduce people practicing open defecation by over 27% between 2000 and 2015 [1]. Even though there has been tremendous improvement in the proportion of households with latrine facilities, the number of households without access to proper sanitation is alarming. Lack of proper sanitation is a major cause for increased risk of poor health, malnutrition, limited education and harassment in the society. Around 60,700 children under age of five in India die of diarrheal related diseases every year [3]. Biological needs of women and girls make them most vulnerable to the effects of poor sanitation right from birth, through childhood, into puberty, throughout adult life, and into old age. WaterAid in 2017 reported that around 355 million women and girls do not have access to toilets in India [3].

Along with access to sanitation for women, women safety is also a critical parameter to be considered which has been a problem for a while in developing nations. Women are

prone to harassment, psychosocial stress and sexual violence while traveling for defecating, either to public toilets or open fields and when they step out of homes in the dark. The hardship faced by women due to lack of proper sanitation facilities is discussed in many literature, and statistics indicate one in every three women face risk, shame, ill health, harassment and violence as they don't have access to safe toilet [14, 15, 16, 17]. Over the lifetime, women and girls experience toilet insecurity in different ways [13]. Inadequate facilities that cause toilet insecurity for women include no access to toilet, risk of going out for open defecation in the absence of toilet and accepting the risk of going for open defecation due to filthy and insufficiently lit public toilets.

The next issue in hand apart from access to sanitation and women safety, is accessible and affordable electricity. India has the third largest consumption of electrical energy (with 1054 Billion Kilo-Watthours) after China and United States [4,5], while the per capita electrical energy consumption was 1010 kWh for year 2014-2015[6]. India became the third largest producer of electricity in 2015 after China and US; it remains a power deficit country due to its low per capita power consumption [7]. In 2011, 33% of rural households were not connected to the grid and depended on kerosene lamps for lighting [8]; recent government reports show that 98.1% of all villages have been electrified as on 2017[9]. Despite the significant progress in village electrification, electrical power supply in the rural areas is marred by power-shortages and load-shedding due to deficit of 0.1-1.2% in energy and peak supply position through various regions of India (all 5 regions: Northern, Western, Southern, Eastern and North Eastern are energy deficient in Peak Power supply and total electrical supply).

To solve the issues discussed and for enabling adoption of the solution, the method that could be considered is Do-It-Yourself (DIY). DIY goods are in existence since the middle of the twentieth century and is gaining popularity throughout the world [21]. DIY can be defined as the accomplishment of home maintenance and improvement by householders without professional help and treat it as an “analytically complex phenomenon, one that simultaneously involves leisure and work, consumption (of materials and tools) and production (of changes to the home)” [22]. As per the literature, benefits of DIY are the freedom of the individual to make the product by themselves wherever or whenever, thereby feeling the satisfaction of ownership of the product, reduction in the cost of goods and expanding the skills among many people which was restricted to only manufacturers earlier [23], [24]. Literature suggests on account of in-depth interviews conducted on self-professed DIYers and the observations on the motivation for the DIYers were mostly either marketplace evaluation or to enhance aspects of their identity [25]. Marketplace evaluation translates to need for customization, lack of product availability or quality and relative economic benefits. On the other hand, few DIYers' motivation was to improve their skills, need for uniqueness. In the mid of twentieth century, the DIY were associated with goods that had very standardized set of instructions to assemble, like the predesigned furniture sold by IKEA [21]. The DIY market in Indian context has been studied and includes a survey on Indian consumers regarding DIY. The most commonly practiced DIY activity was electrical work, and general household repair rather than household improvement and

a critical factor identified was the knowledge of materials, products and usage [26]. The 51% of the respondents felt that self-satisfaction was the important reason for taking up the DIY [26].

2 Design Methodology

The section discusses the needs of the targeted population, design requirements of the solution, conceptual design and development process. The problems faced by the rural population due to lack of electricity were understood by studying existing literature and reports. The cases considered while designing the DIY product are: i) Community toilets in villages which lack good electricity connections ii) No electricity connections in the toilet. iii) The household does not have electricity connection iv) The villages are not connected to the electricity grid and the people have access to mobile phones and they may need to travel far to get it charged.

The scenario of affordable electricity and low infrastructure maintenance costs were considered as well in the ideation phase. Based on the need assessment, the main needs that were identified are safe sanitation and low-cost solution for better access to electricity. The design requirement for the solution based on the needs assessed is shown in Fig. 1. The reuse of materials was the central theme in the design process based on which the concept was designed.

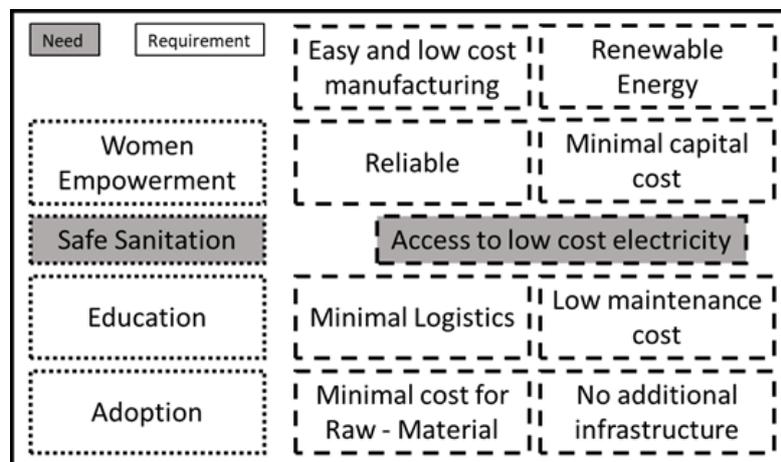


Fig. 1. Identified Design Requirements of the solution

| | Opt. 1 | Opt. 2 | Opt. 3 | Opt. 4 | Opt. 5 | Opt. 6 |
|--------------------|-----------------|----------------|--------------------|--------------|------------|--------|
| Energy Source | Solar | Hydro | Wind | Nuclear | Biomass | |
| Operation Mode | Automatic | Manual | Semi-Automatic | | | |
| Control Type | Digital | Analog | Mixed | | | |
| Sensors | PIR | Ambient Light | Sound | Video | Ultrasound | Nil |
| Light Source | LED | CFL | Mercury | Tube light | | |
| Manufacturing Type | Additive | Conventional | DIY | | | |
| Enclosure | Moulded Plastic | Reuse of Waste | Cardboard | Paper | | |
| Maintenance | Expert | Self | Disposable | Replacement | | |
| Energy Storage | Nil | Battery | Storage Tank | Transmission | | |
| Type of power | AC | DC | | | | |
| Auxiliary Feature | Mobile Charging | Cooking | Water Purification | | | |

Fig. 2. Morphology Matrix of Concept Design

The Fig.2 shows the multiple options as a result of brainstorming among the group, for various parts in the system being designed. The initial concept was a microcontroller-based DIY design which incorporated digital logic with the help of sensors. The thought process of the initial design was to provide additional functionalities which could be later used by the youth to experiment their ideas by extending the application. The concept utilized the LDR and PIR sensors to sense the ambient light and motion of a person which would control the light. The control algorithm was embedded in a microcontroller. The concept allowed flexibility. The enclosure used was a 1 litre packaged drinking bottle. The concept was developed and showcased in a public forum to understand the reactions of public. The response among the audience was positive, and people especially young kids were attracted towards the prototype and the idea behind DIY. A limited validation was carried out for the concept by a small group of kids to understand their feedback on the DIY based system.

With the feedbacks received by the kids and audience of the forum as discussed above, further deliberations within the team were carried out. Concerns on durability of the enclosure for the initial concept and the cost involved in using a micro-controller-based solution were raised. Based on the concerns, various options for enclosures using 3D printing, origami, cardboard, PVC pipe etc. were discussed. The electronics was modified to an analog-based control which did limit its flexibility in reprogramming but, reduced the cost by around 20%. Finally, based on couple of iteration the enclosure was modified to a PET bottle and the concept was redesigned. The block diagram of initial microcontroller-based concept is shown in fig.3a, the modified analog concept is shown in fig. 3b, fig.4a and 4b shows the materials used, assembly and testing of the initial concept.

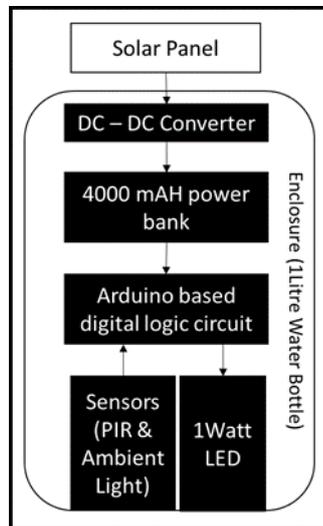


Fig. 3a. Block Diagram of Microcontroller based Concept

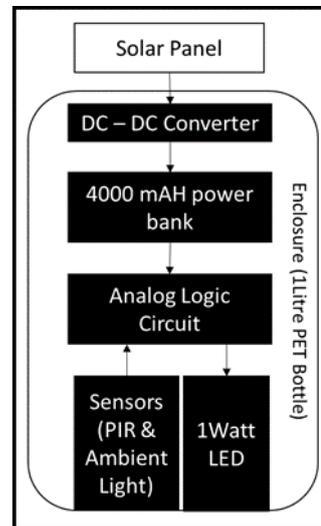


Fig. 3b. Block Diagram of Modified Analog Concept

The new concept will be further developed, and a small batch of prototypes will be taken for field trials in a rural environment in coming few months for user verification and validation. The DIY method and its efficiency in solving the identified needs will be tested in the process. Finally, based on the feedback the project will be further scaled and few hundred units would be distributed to the rural areas.

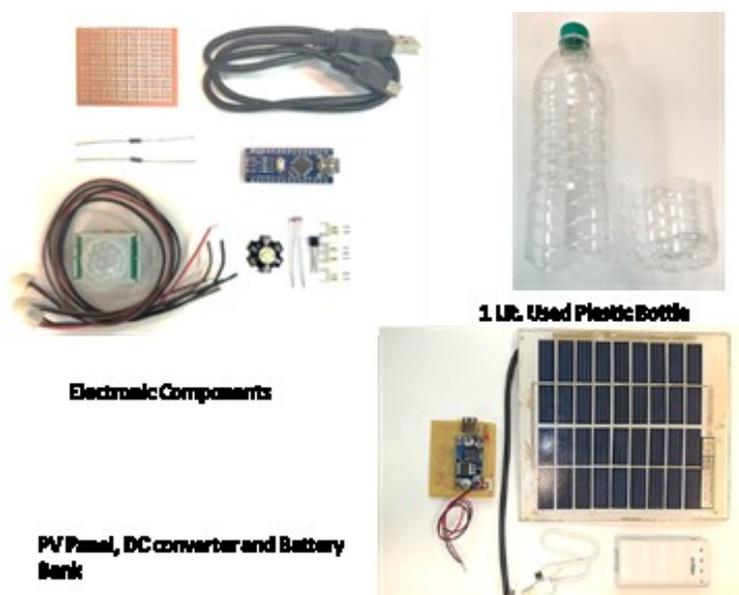


Fig. 4a. Materials used in Initial Concept

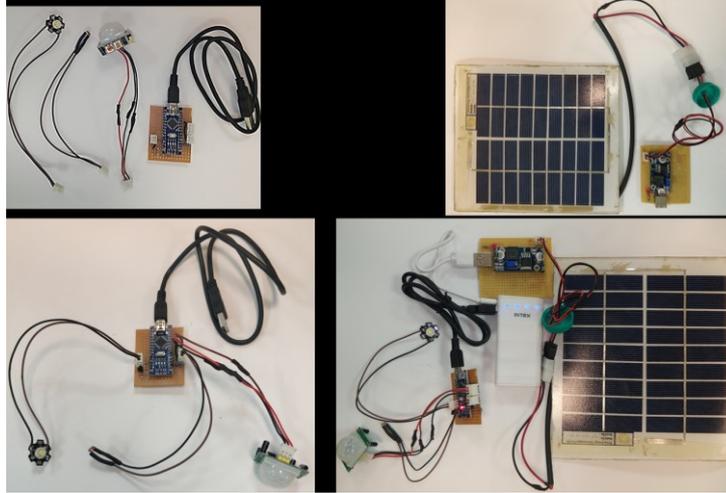


Fig. 4b: Assembly and functional testing

3 Discussion

The issue of poor sanitation leads to gender gap in workplace, attendance drops among school going girls to the extent of dropping out from school when a girl reaches puberty, risk of sanitation related diseases, assaults and various threats to safety and health of women. Global sanitation crisis has far-reaching consequences, ranging from health of individuals to economy of nations which makes it paramount to address the problem with utmost attention. At the same time, addressing the sanitation crisis requires intervention from government as well as private organization through construction of toilets in households, schools and workplaces should be accompanied by campaigning the importance of sanitation, especially in rural households. Also, empowering people for solving their problems and meet their needs by themselves is important. The product is designed to provide hands on experience to people which could help in understanding of the basic engineering and design involved in current technology solutions, and in this process also make people understand the importance of sanitation.

Apart from sanitation, safety of women is also a problem in India [18]. It is reported that two girls in Uttar Pradesh state were raped and hanged while they were going to field for defecating [18]. 400 women would have escaped from rape, if they had toilets at their homes, as said by a senior official from Bihar [18]. Specific cases were reported where girls under ten years being raped while going to use public toilet, in the urban slums of Delhi [18]. Literature discuss that women in a few settlements have to go up the nearby hills for defecating at night or early morning under the cover of darkness, due to safety issues they face during the daytime [19]. They go in groups as well, to feel safe. Many even eat less to relieve themselves during daytime. A project that focuses on empowerment of rural people must include aspects of sanitation with focus on women and girls. It builds their access to resources and skills. It also enhances their

inner capability thereby empowering them. Empowering women of the society is both, the means and termination to the insecurity prevailing in a society. If we can address the toilet insecurity of women, we will be able to address the crisis on sanitation globally. Therefore, access to private toilet is an urgency to benefit the women who are living without access to safe toilet conditions. Innovative approaches can address many development challenges including sanitation [29]. We aim to empower women in rural areas to understand the importance of safe sanitation through our project. We expect our solution to have adequate lighting so that women can safely use their toilets at any time without fear and anxiety of darkness, be it public or private toilet.

Looking at the electricity access and energy resource scenario of India, the solar energy generation potential of India is quite high (at 6000 Million GWh energy per year) as it receives 4-7 kWh of solar radiation per square meter per day with 250-300 days on an average [12]. Hence it has tremendous potential for photovoltaic (PV) based solar energy generation. The primary power needs of rural homes are lighting, fan, mobile-charging and entertainment. Basic artificial lighting is one of the primary needs for daily activities of rural households. The fundamental function of a home-lighting system is to provide safe lighting environment for visual tasks, movement around spaces, colour rendering similar to natural light and safety from snakes, wild animals and miscreants [10]. Cooking, daily chores and other allied agricultural activities also need artificial lighting. LED-based artificial lighting technology has been a revolution in the rural scenario as it has a long life, low cost and consumes less power. A PV based standalone LED lighting system can potentially reduce the energy deficit related to electricity generation. Moreover, such a system would enable people in remote villages use the lighting energy more conveniently and independent of the grid. Further, it has the potential to bring a larger rural population under safe and well-lit sanitation scenario. The maintenance and repair of such system could be taken care by imparting of innovative training and educational awareness about the electronic lighting system used in such modules. Barefoot college (located in Tilonia Village, Rajasthan) which provides training to rural women (mostly illiterate or very low educational profile) and turns them into solar engineers can be seen as an experimental case [27]. With our solution, we have attempted the possibility and over the period of time, we could analyze the impact created.

Finally, considering the DIY approach used in this project we expect that it could have a potentially disruptive dissemination model for product as well as the method to educate people on importance of sanitation. Over time, there has been a paradigm shift in the DIY goods. The advancement in the technology has enabled the DIY goods to be more versatile and allows an individual to implement his/her creative ideas. The shift has been observed in many fields, like newspaper, music industry and especially electronics. DIY is also a good pedagogy tool for people to upskill and thereby improve their opportunities to enhance their income. Incidentally, DIY systems also help in reducing the cost of assembly, packaging and support for the manufacturers of products and thereby, a possibility of bringing in low cost solutions in the market. Exploiting the

advantages inherent in the DIY products coupling with the intention of providing a solution to existing societal issues of secured sanitation and affordable lighting in rural area is the motivation behind our product design.

4 Conclusions

The DIY design model approach is expected to be effective in utilizing the technology to encourage better sanitation facilities for rural people, especially for women and girls. The design makes use of reusable and accessible materials, combined with technical know-how to help the young rural minds to explore and experiment with the latent creative-hacking spirit of a rural Indian.

Field trials are planned to be carried out over next few months for user verification and validation of the concept. We expect that the model can encourage the local populations to find effective solutions for problems faced by them. Finally, we also aim to spread the message of design, innovate and make it yourself in India.

References

1. WHO and UNICEF, “Progress on Drinking Water, Sanitation and Hygiene,” 2017.
2. National Buildings Organisation, “State of Housing in India: A Statistical Compendium,” 2013.
3. WaterAid, “Out of Order: The State of the World’s Toilets 2017,” 2017.
4. Conti J, Holtberg P, Diefenderfer J, LaRose A, Turnure JT, Westfall L (2016) International Energy Outlook 2016 With Projections to 2040. USDOE Energy Information Administration (EIA), Washington, DC (United States). Office of Energy Analysis
5. Energy Information Administration (EIA) (2015) Total Electricity Net Consumption - 2015.
6. CEA Government of India (2017) Power Sector. New Delhi
7. Harish SM, Iychettira KK, Raghavan S V., Kandlikar M (2013) Adoption of solar home lighting systems in India: What might we learn from Karnataka? *Energy Policy* 62:697–706. doi: 10.1016/j.enpol.2013.07.085
8. Government of India (2017) Progress report of village electrification as on March 2017. In: Gov. India. <https://data.gov.in/catalog/progress-report-village-electrification>. Accessed 7 Jan 2018
9. Bhusal P, Zahnd A, Eloholma M, Halonen L (2007) Replacing fuel-based lighting with light emitting diodes in developing countries: Energy and lighting in rural Nepali homes. *LEUKOS - J Illum Eng Soc North Am* 3:277–291. doi: 10.1582/LEUKOS.2007.03.04.003
10. Wresearch (2017) India LED Lighting Market (2017-2023).
11. Tripathi L, Mishra AK, Dubey AK, Tripathi CB, Baredar P (2016) Renewable energy: An overview on its contribution in current energy

- scenario of India. *Renew Sustain Energy Rev* 60:226–233. doi: <https://doi.org/10.1016/j.rser.2016.01.047>
12. O'Reilly, K., 2016. From toilet insecurity to toilet security: creating safe sanitation for women and girls. *Wiley Interdisciplinary Reviews: Water*, 3(1), pp.19–24. Available at: <http://doi.wiley.com/10.1002/wat2.1122>
 13. Wsscc, WaterAid & Unilever Domestos, 2013. *We Can't Wait - A Report on Sanitation and Hygiene for Women and Girls.*, p.28. Available at: <http://worldtoilet.org/wp-content/uploads/2014/02/WecantWait1.pdf>
 14. Carter, R. & Howsam, P., 1999. The Impact and Sustainability of Community Water Supply and Sanitation Programmes in Developing Countries. *Water and Environment Journal*, 13(4), pp.292–296.
 15. Kapur, D., Ramisetty, M. & Barot, N., 2016. Formative research to develop appropriate participatory approaches towards water, sanitation, and hygiene in rural areas., (May).
 16. Sida, 2015. (BRIEF) *Women, Water, Sanitation and Hygiene. Gender Tool Box*, (March), pp. 1–5
 17. Biswas, S., 2014. Why India's sanitation crisis kills women. Available at: <http://www.bbc.com/news/world-asia-india-27635363>.
 18. Bapat, M. & Agarwal, I., 2003. Our needs, our priorities; women and men from the slums in Mumbai and Pune talk about their needs for water and sanitation. *Environment and Urbanization*, 15(2), pp.71–86.
 19. Melchior-Tellier, S., 2009. Women, Water and Sanitation. *Water International*, 16(3), pp.161–168.
 20. Stephen Fox, (2013) "Paradigm shift: do-it-yourself (DIY) invention and production of physical goods for use or sale", *Journal of Manufacturing Technology Management*, Vol. 24 Issue: 2, pp.218-234, <https://doi.org/10.1108/17410381311292313>
 21. Watson, M. and E. Shove (2005). "Doing It Yourself: Products, Competence and the meaning in the practices of DIY". Paper presented at the European Sociological Association Conference, Torun, Poland, September 2005.
 22. Norton, M.I., Mochon, D. and Ariely, D. (2011), "The 'IKEA effect': when labour leads to love", *Harvard Business School Marketing Unit Working Papers No. 11-091*.
 23. Williams, C.C. (2004), "A lifestyle choice? Evaluating the motives of do-it-yourself (DIY) consumers", *International Journal of Retail and Distribution Management*, Vol. 32 No. 5, pp. 270-8.
 24. Marco Wolf and Shaun McQuitty (2011), "Understanding the do-it-yourself consumer: DIY motivations and outcomes", *AMS Rev* (2011) 1:154–170
 25. Vidosh Sarup (March 2008), "DO-IT-YOURSELF MARKET IN INDIA: EXPLORING DEVELOPMENT AND SERVICING OF DEMAND FOR PRODUCTS RELATED TO HOUSEHOLD PAINTING AND CARPENTRY", An MSc Engineering thesis submitted in Faculty of

- Engineering, Dept of Management Studies, Indian Institute of Science, Bangalore.
26. Nair RJ (2015) Indian College turns Rural Women into Engineers. <https://www.barefootcollege.org/indian-college-turns-rural-women-into-engineers-2/>.
 27. UNICEF & World Health Organization, 2017. Progress on Drinking Water, Sanitation and Hygiene. Unicef, pp.1–66.
 28. Andersson, K., Otoo, M. & Nolasco, M., 2018. Innovative sanitation approaches could address multiple development challenges. *Water Science and Technology*, 77(4), pp.855–858.