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IDENTIFYING ENERGY NEEDS FOR RURAL ELECTRIFICATION PROJECTS IN OFF-GRID COMMUNITIES

Martinez, Lucas Rodolfo [(1)]; Bastida Molina, Paula [(1)]; Ribó-Pérez, David [(1)]; Hurtado Pérez, Elías [(1)]; Peñalvo López, Elisa [(1)]

[(1)] Universitat Politècnica de València

Local Off-grid, renewable energy electricity generation systems are proving to be a viable solution for achieving SDG 7 without undermining SDG 13, especially in isolated communities in emerging countries. However, the scarcity of resources for development aid requires tight designs that minimize these systems' investment and operational costs. To this end, it is necessary to precisely define the "sufficient" energy demand to promote the endogenous development of the beneficiary community. This is difficult because there is no previous data on energy consumption. This project reviews the state of the art on the identification of energy needs in communities that have not previously consumed electricity. Techniques based on energy simulation are not applicable due to the poor quality of the data: building materials, local climate files, expected uses, etc. Deterministic techniques do not take into account the variability of energy demand, and stochastic techniques require precise knowledge of future energy behavior. A new approach based on the most widespread methods is designed and applied to a case study in Honduras.

Keywords: identification of energy needs; hybrid renewable energy systems; rural electrification projects; off-grid communities; development cooperation

IDENTIFICANDO LAS NECESIDADES ENERGÉTICAS PARA PROYECTOS DE ELECTRIFICACIÓN RURAL DE COMUNIDADES AISLADAS DE LA RED ELÉCTRICA

Los sistemas locales de generación de electricidad a partir de energías renovables sin conexión a la red están demostrando ser una solución viable para alcanzar el ODS 7 sin menoscabo del ODS 13, especialmente en comunidades aisladas de países emergentes. Sin embargo, la escasez de recursos para la ayuda al desarrollo exige diseños ajustados que minimicen los costes de inversión y funcionamiento de estos sistemas. Para ello, es necesario definir con precisión la demanda energética "suficiente" para promover el desarrollo endógeno de la comunidad beneficiaria. Esto es difícil porque no existen datos previos sobre el consumo de energía. Este proyecto revisa el estado del arte sobre la identificación de las necesidades energéticas en comunidades que no han consumido electricidad previamente. Las técnicas basadas en la simulación energética no son aplicables debido a la escasa calidad de los datos: materiales de construcción, archivos climáticos locales, usos previstos, etc. Las técnicas deterministas no tienen en cuenta la variabilidad de la demanda energética, y las técnicas estocásticas requieren un conocimiento preciso del comportamiento energético futuro. Se diseña un nuevo enfoque basado en los métodos más extendidos y se aplica a un estudio de caso en Honduras.

Palabras clave: identificación de necesidades energéticas; sistemas híbridos de energías renovables; proyectos de electrificación rural; comunidades sin conexión a la red; cooperación al desarrollo.

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1. INTRODUCTION

The World Energy Council's global scenario indicates that 733–885 million people will lack access to electricity in 2030 (Panos et al., 2016). The rural population is the most disadvantaged with a share of 17.5% (IEA, 2021). Electricity is crucial for poverty alleviation, economic growth, and improved living standards. It provides social development, reduces migration, facilitates education and health care, breaks the barrier of communication and access to information, and fights against climate change and gender equality (IRENA, 2019).

In recent years, there were significant efforts for the rural electrification of isolated communities. However, it is not economically or environmentally sustainable to replicate the industrialized country's model of oversizing the generation and distribution of electricity. The 2030 Agenda has set the goal of universal access to electricity by 2030. This is a clear call to action, which implies significant efforts. It involves reaching a population with limited incomes, often living in sparsely populated areas, mostly in developing and least developed countries. (UN SDG, 2015).

The literature discusses two main pathways to supply electricity: on-grid and off-grid. Grid extension is not feasible, especially when long distances to the main grid and a small and dispersed population exist. In these cases, off-grid systems are used to deliver clean, affordable, reliable, sustainable, and modern energy. Providing electricity to rural communities through off-grid solutions presents additional benefits such as resilience to climate change and resilience to power supply (Ortega-Arriaga et al., 2021).

One of the main obstacles lies in the lack of financial resources. Therefore, there is a need for sustainable and cost-effective solutions for the electrification of rural areas. When designing an off-grid system, the energy demand assessment becomes critical to ensure the proper sizing of the components. The lack of data directly influences the quantification of the energy demand, thus resulting in under or over-dimensioned systems (GIZ, 2016).

On the one hand, oversizing will increase investment, operational, and maintenance costs and consequently, the payback period. On the other hand, an undersized system will result in a lack of reliable and continued energy supply, generating discontent among the customers and forcing the component´s operation. Both situations do not escape the most feared risk "user disconnection" which leads back to the previous situation of poverty or even worse. Therefore, a proper demand analysis must be developed. Consequently, a balance to provide cheaper and more accurate but also reliable designs may attract more private investments.

To identify the energy needs in the past decade, many studies consider a simple assumption that a community is exactly like another. Therefore, varying the number of consumers, consumer type, and activities or growth rates to predict the load. Some studies base the demand assessment on expert knowledge in similar installations, usually assuming averaged daily constant load profiles (Louie, 2018). Other studies propose mathematical models based on statistics. These models require specific input data for each area and can only be gathered through on-site surveys and measurements (Herraiz-Cañete et al., 2022). It remains unclear which is the best pathway to determine the energy needs of communities that have never had access to electricity before.

The objective of this study is to review the state of the art, critically select the methods and tools, and apply them to a real case study. Along the way, it was found that many of the existing tools are not open-access, which led to the creation of a tool to process the data and subsequently use software to obtain more realistic results. The rest of the paper is structured in chapters as follows: Section 2 presents the literature review, whereas Section 3 presents the methodology and explains the step-to-step for the application case. Moreover, Section 4 shows the main results and discussion and finally, section 5 concludes, recommends, and addresses future efforts.

2. LITERATURE REVIEW

To assess the electricity demand, there are different methodologies but no one is generally accepted. Many authors stated that load estimation is the most difficult aspect of successfully developing an off-grid system (Louie, 2018). Error rates of more than 300% have been reported (Blodgett et al., 2017). Certain data is always needed for an accurate technical design and financial modeling. The peak load in kW (for load forecast, and plant design) and the energy demand in kWh (for demand forecast and revenues).

The electricity demand also depends on other factors such as customers' income and their ability to pay (ATP) for electricity services, which in turn depends on current expenditures on other energy sources (wood, kerosene, candles...), and willingness to pay (WTP) (RECP, 2014). These parameters must be evaluated to ensure the sustainability of the project over time. A household is at risk of losing the ability to pay when it represents over 5-10% of the household spending (Lakner et al., 2020). It has been demonstrated that these parameters affect the consumption behavior of electricity (GIZ, 2016).

Other authors add that the future energy demand depends on other factors that vary during the life of the off-grid system: i) socioeconomic factors, such as population, economic growth, lifestyle, and consumption patterns (Sahu et al., 2013), and ii) temporary and climatic factors, which change throughout the year, but also over the years (Mahrufat et al., 2016)

When identifying future energy needs, it is necessary to classify different types of load profiles such as community services (education, street lighting, healthcare, water supply, public institutions, etc.), households (lighting, electrical appliances, space cooling/heating, cooking and water heating, etc), and productive uses (irrigation, agriculture, crop processing, markets, bars, etc). Each of these categories consists of a variety of very different consumers with distinct and diverse energy consumption patterns, resulting in a complex composition of the community energy demand. In every case, electricity access data is adjusted to be consistent with the demographic patterns of the urban and rural populations. The process can include several steps as an initial demand assessment (through surveys), an effective demand calculation (using correlation factors), and future demand forecasting.

The literature addresses four approaches to estimating the load curve: bottom-up, survey, regression, and data-driven (Louie, 2018). A comprehensive review of load profile models classifies them into bottom-up, top-down, and hybrids. Furthermore, the methods are divided according to the sample rate: low resolution (hours - 15 minutes), middle (15 – 1 minute), and high resolution (1 minute – hertz) and according to the statistical modeling: Markov Chain, Probabilistic, and Monte Carlo models (Proedrou, 2021).

A hybrid model to generate the load profile based on a combination of synthetic load profile, data-driven and statistical parameters was validated by comparing the simulation results with measured data (Kühnel et al., 2021). This option is attractive when multiple sources of information are available. Deterministic and stochastic models were compared. Deterministic assumes there is an exact relationship among the variables, thus there is no error and the results are rigid and static. On the other side, stochastic considers the randomness of the variables that define load prediction and provide a more accurate picture of the scenarios in which demand will occur (Herraiz-Cañete et al., 2022)

The tools to process the information can be consulted online (Energypedia, 2023). Among these, the following stand out: Mini Grid Builder (GIZ), Demand Analysis (IED), VIDA (TFE), and ODESSEY. Some tools, but not found in this portal, are: The load profile generator (LoadProGen)+RAMP model which forms one of the most comprehensive and functional stochastic tools (Lombardi et al., 2019), and determinists models such us neural networks, linear regression, multiple linear regression, ARIMA, and LASSO (Allee et al., 2021)

The literature shows the comprehensive and complex process that means identifying a community's energy needs without electricity. Table 1 formalizes the different definitions and attributes of a load forecasting process. It is intentionally made to show from higher (top) to lower (bottom) labor intensity. On the one hand, the most laborious case would be to forecast the load curve with a bottom-up method, using only primary information collected through microscopic scale fieldwork (device by device), with a resolution of hz, for a long term of 25 years using stochastic modeling (which is practically unfeasible). On the other hand, the most laborious case would be to follow a top-down approach, with secondary data, evaluating the whole community with a simple estimation, using an hourly resolution for a period of one year (which is not accurate).

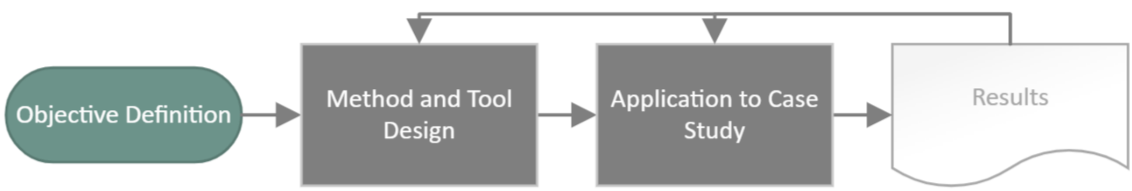
Table 1 formalization of the different definitions and attributes of a load forecasting process

Method	Source of information	Scale	Resolution	Time frame	Modeling
Bottom-	**Primary**	**Microscopic**	Hz	25 years	**Stochastic**
Up	Fieldwork,	Appliance to			Markov Chain
	Surveys	appliance	**High**	**Long**	
	Interviews	Person to			
		person	1 min	10 years	
	Private,	Household to			
Hybrid	Public,	household	**Medium**	**Medium**	Monte Carlo
	NPO	Archetypal			
	statistics	cluster	15 min	5 years	
	and reports				
	Data-Driven				
	Literature	Entire	**Low**	**Short**	
Top-	Web portals	community			Probabilistic
Down	**Secondary**	**Macroscopic**	1 hour	1 year	**Deterministic**

3. APPLICATION CASE

Figure 1 shows the methodology proposed in this paper. The method starts with the objective definition. Then, a literate review explores existing methods and tools. The most relevant are critically evaluated and selected. A new method and tool are structured based on the most relevant existing ones to perform a determinist load curve. Subsequently, HOMER software is used to sketch a stochastic and annual curve. A case study is applied to illustrate the method.

Figure 1: Methodology for the load curve identification



3.1. Objective definition

The objective is to identify the energy needs of a community and convert it into a load curve. The process will follow a bottom-up approach using household-to-household surveys for the collection of primary data. The survey should be useful for the characterization of the community (socioeconomic and demographic). The resolution of the load curve will be hourly in a time frame of 5 years. The load curve design will follow a deterministic model and posteriorly it will be turned into a stochastic one.

3.2. Methods and tools design

Based on a survey approach, the most relevant tools found in the literature are the ones performed by: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ, 2016), the U.S. Department of Energy and National Renewable Energy Laboratory (NREL, 2020) and World Health Organization (WHO et al., 2019). The tools to process the information are not open-access. This leads to the creation of a proprietary method and tool.

The surveys analyzed are time demanding. The number of appliances, power, and operating time (current and future up to 5 years) are asked twice. That approach leads to substantial errors, even more, when the users have no prior knowledge of the uses of electricity. For this reason, an energy level approach will be used instead. The fact of identifying types of users is more practical than individual users. To design the survey the best practices stated by NREL will be followed.

The new questionnaire is divided into 3 sections: 1 Household (required), 2 Households (recommended), and 3 Community Leader/s (required). The recommended information is useful for understanding the project and the characterization of the community, but is not required for the identification of the load curve. The information will be processed in an Excel sheet to make the deterministic curve, and posteriorly, the software HOMER will be used to make it stochastic. The survey can be seen in the annexes with sample responses.

3.3. Case study: El Santuario (Honduras)

The surveys were conducted by the research team and applied to 75 households and the community leader of El Santuario, Choluteca, Honduras. Google Forms online tool was used to save the information. There are many options in the market such as SurveyMonkey, Quick Tap, Odessey, KoBo Toolbox, or even Microsoft Office (Word and Excel). Sections 1 and 3 took an average of 5 minutes per person to complete. Section 3 took an extra 10 minutes per person. Considering the time to walk from house to house and organize the interview the work was done in 4 days (8 hs/day, 32 hs in total, 25 min/household on average). If applying only section 1 for households the total time would be significantly reduced. If resources permit, it is important to survey all households to geolocate the dwellings. If the population is too large, a sampling size with a confidence level and margin of error should be considered to expedite this process.

4. RESULTS AND DISCUSSION

The results of the survey - section 2 collects the data for the characterization of the community. El Santuario is located in the province of Choluteca, southern Honduras. Its coordinates are 13°29'N; 87°22'O. More than 400 inhabitants are distributed in 75 dwellings with an average of 5.4 persons/household. Currently, there were 5 more dwellings uninhabited. 75% of the households are in the range of 45 - 60 years old, and the majority have been living in the community since borned. 87% of the households are male, 75% married, and with an average of 3 soon per/household. 36% with children under 18 years old. Less than half of the children are attending school. Among the households, 35% stated having at least some level of education.

Among the inhabited dwellings, there are 69 in the main urban nucleus, and 6 more in another small group of dwellings 2.5 km away. The dwellings are on average 56 m^2 constructed with a standard deviation of 15 m^2. The distribution of the construction material matches the following distribution: 60% concrete, 25% crumbling concrete, 7% bricks, 5% wood, and 3% vanner.

Usually, a dwelling consists of a kitchen and a living room as a shared space and a certain number of bedrooms. Currently, the occupied dwellings have an average of 2.4 sleeping rooms There are 92% of owners and the remaining do rent.

Currently, most households use kerosene, candles, and battery-powered lanterns for household lighting, firewood for cooking, lighting, and heating; and batteries for powering portable radios and flashlights. There are 7 dwellings that have small solar photovoltaic and battery systems for home lighting and cell phone charging. These systems consist of a small solar panel of about 50 W, an inverter, and a battery of 12 V - 9 Ah.

93% of the respondent said that access to a modern electricity supply would improve their lives, the remaining 7% stated that they did not know whether or not access to modern electricity would or would not improve their lives, and no community member expressed discomfort or opposition to the electrification process.

The local economy is mainly based on subsistence agriculture and seasonal agricultural work. The surplus for commercialization is minimal. Currently, the reported average monthly expenditure on energy sources amounts to 5.56 USD/household per month, with a standard deviation of 2.63 USD. The predominant part of this expenditure is the purchase of kerosene bottles and batteries. The consumption of forest biomass does not represent an economic cost.

The community's inhabitants have an average willingness to pay an extra 5 USD per month for electricity. Therefore, adding the average monthly costs and the average monthly willingness to pay there is an estimated ability to pay of 10.56 USD per month for electricity. They are predisposed to pay and understand electricity will not be free even though 35% of the respondent are expecting subsidies to afford the cost of electricity. 98% stated that the cost is more important than the quality or duration of electricity.

The average income per household is 110 USD/month. Due to the seasonality, it varies between 160 USD/month in high season and 40 USD/month in low season. In addition, 88% said that they would pay for the electricity consumed and could help to generate cash flow to cover the costs of amortization, maintenance, and possible expansions. The rest agreed conditionally e.g., “If I succeed in business and my children can go to school in Choluteca”. Regarding mobility, the identified consumptions are usually solved with human or animal energy. When it is necessary, hardly ever, a truck is hired to take or send things to Choluteca.

The results of the survey – section 1&3 collect the data for the load curve. The electrical appliances and power consumption were consulted in the Honduran national energy web portal (ENEE, 2023). The distribution of consumption was performed according to their habits pattern. The average inhabitants get up at 6:00 am, come back to lunch at 12:00 pm, go out and come back home at 18:00 pm, and go to sleep at 23:00 pm. The profile of each type of consumer is tailored to be consistent with the Honduran socioeconomic and demographic patterns and can be seen in Figure 2. As a result of the survey, there are 7% low consumers (< 240 Wh/day; green), 65% medium (< 630 Wh/day: yellow), 24% high (<1.970 Wh/day; light blue) and 4% very high (< 4.970 Wh/day; red). Each dwelling is geolocated. In the lower part of Figure 2 is the distribution of the urban cores and in the upper part the dispersed ones. Note that the abandoned dwellings are with white pins.

The sector, consumer type, and total energy demand can be seen in Table 2. Some correction needs to be done due to variations during the weekend when some productive and social uses are off or less (keeping in mind that the refrigerators are never turned off). Another correction should be done if 10% of the average income of the households were not enough to pay for the level of electricity chosen. The surveys reveal that it is not the case for the households in El Santuario. No consumption of work or industrial mechanical energy has been detected. Due to their low incidence, intermittency, and the unpredictability of their use, these consumptions are not included in the demands to be covered.

Figure 2: Household distribution, load curve, and share of consumer type.

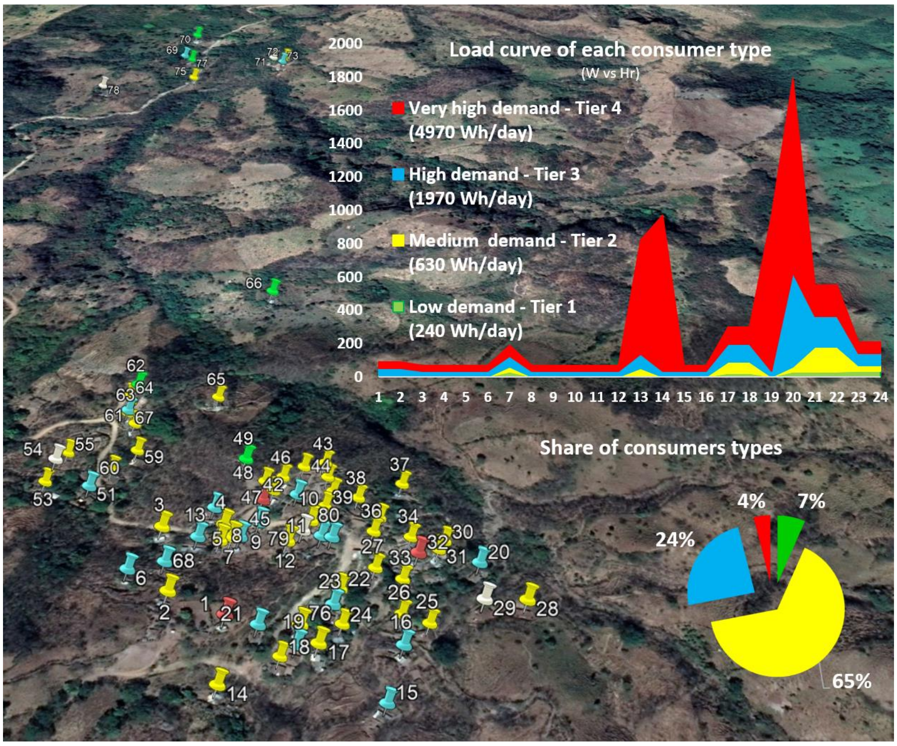
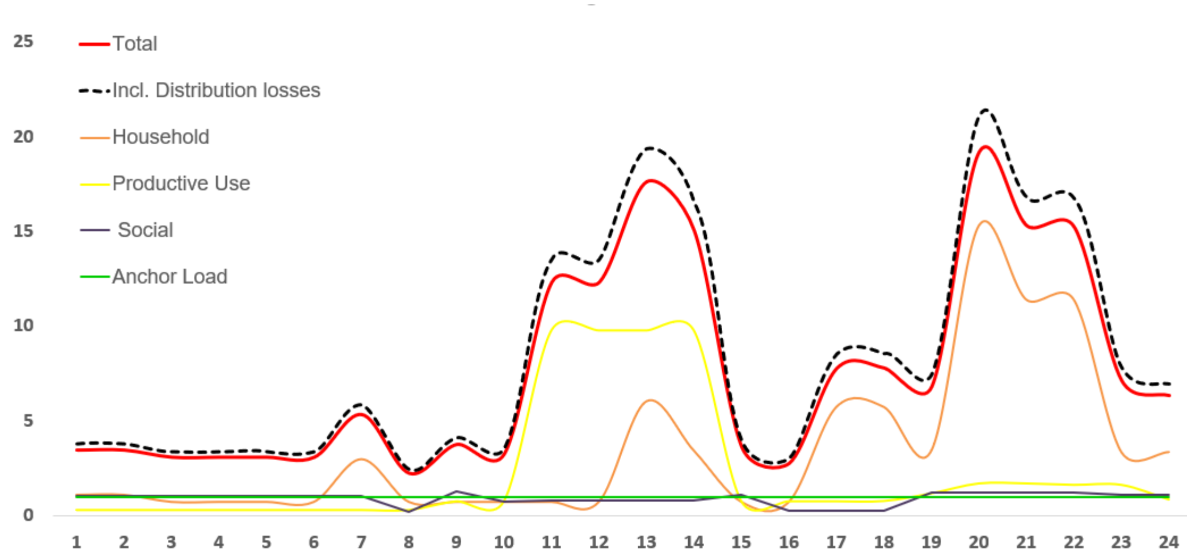


Table 2. Energy demands calculation for consumer types and community

Sector	Consumer Type (ct)	nº of end-user	Energy cons.type (Wh/dy.ct)	Energy Weekday (kWh/dy)	Energy Weekend (kWh/dy)
Household	Low demand Tier1	5	240	1,2	1,2
Household	Medium demand Tier 2	49	630	30,9	30,9
Household	High demand Tier 3	18	1.970	35,5	35,5
Household	Very high Tier 4	3	4.970	14,9	14,9
Productive	Restaurant	2	4.140	8,3	8,3
Productive	Bar	2	3.255	6,5	6,5
Productive	Shop	3	1.320	4,0	4,0
Productive	Barber/Hairdresser	1	300	0,3	0,0
Productive	Guest House	1	0	0,0	0,0
Productive	Water Pump	3	12.000	36,0	36,0
Social	Street Lights	20	13.000	13,0	13,0
Social	School	1	2.505	2,5	0,0
Social	Church	1	1.125	1,1	1,1
Social	Health care facility	1	2.115	2,1	0,8
Social	Hall	1	2.200	2,2	0,0
Anchor	Internet Tower	1	24.000	24,0	24,0
Subtotal		93		182.4	176,2
			Daily average	180.6	
			Including loses	198.7	
Total electricity (year nº 5)				**72.525,5 kWh/yr**	

The data collected and processed by the tool can be seen in Figure 3. It shows the typical weekday load curve for the entire community. Also, it can be seen how each sector contributes individually. The total load curve used is the one that includes losses. The same type of graph can be done for a typical weekend. The different sectors' consumption is distributed as follows: 45% households, 30% productive uses, 12% social, and 13% anchor load.

Figure 3 Typical daily load curve for a weekday for El Santuario (kW vs hs).



The typical deterministic weekday and weekend load curves are converted into a stochastic yearly one. The social, productive, and anchor load are not expected to vary appreciably in a typical week, while the behavior of the more than 400 people living in the community is more random. A variability of 10% day-to-day and 15% timestep-to-timestep is applied. The results can be seen in Figures 4, 5,and 6. Figure 4 shows the average, min, and max monthly values. The system must be prepared to tolerate a pick of 33 kW to avoid a blackout among other undesired. Figure 5 shows the daily and hourly values of the demand. As it was expected, the max pìcks values are around 20:00 and 22:00 hr. In Figure 6 it can be seen how the day-to-day and time-to-time, and weekday/weekend variability is applied. In this random example the first week of January. Most of the weekend consumes less than the weekday.

Figure 4 Average, minimal, and maximal monthly power values.

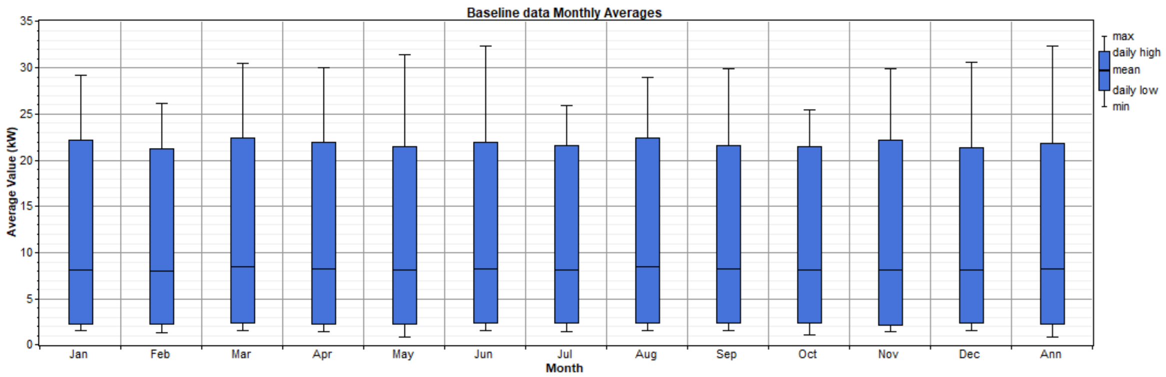


Figure 5 Daily and hourly power values for one year.

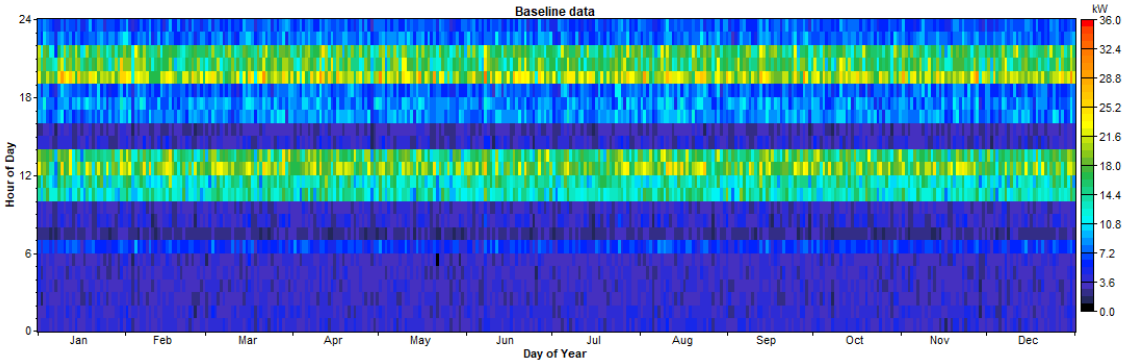
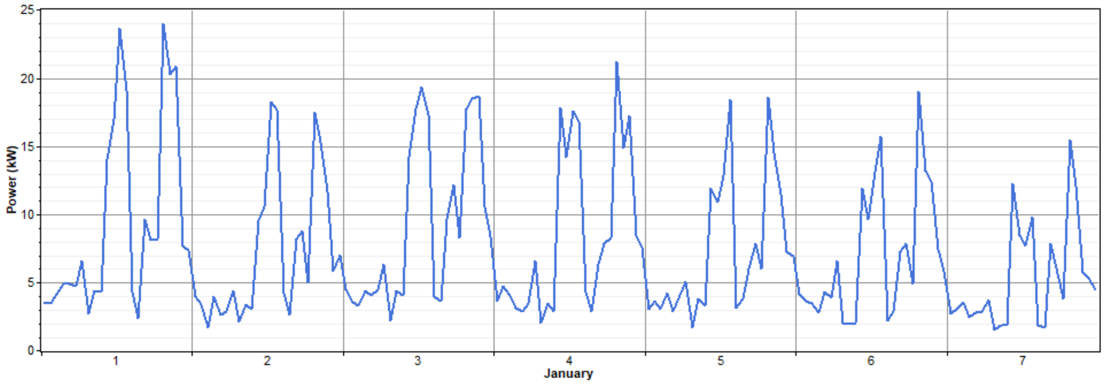


Figure 6 the day-to-day and time-to-time variability.



Some discussions on the work are presented. First, a data-driven approach is not yet recommended because of the scarcity of data. Of the 5,544 installed mini-grid projects, only 0.4% are in Latin America. The case of Asia, with 60%, followed by the Sub-Saharan Africa region with 39% makes more sense to apply this approach (Sustainable Energy For All, 2020).

Currently, most of this equipment does not exist in the community, and furthermore, their acquisition will not be immediate. As the community develops economically, this number of equipment and hours of consumption can be far exceeded expansions. Much more if they decide to start a mini-industrial business such as the elaboration of fermented beverages, jams, or dry fruits among other possibilities. In addition, some members of the community stated that relatives are interested in returning to El Santuario when electricity is available.

The climatic characteristics of the region are tropical. Temperatures are stable and no priority demands for air conditioning or thermal energy installations are foreseen. However, respondents stated that they will have an air conditioner because of the comfort experienced in the homes of family and friends outside the community. If community members adopt this trend as social status, they are likely to start acquiring these appliances more frequently, which means moving to a very high consumption level or level 4. To avoid this, it will be necessary to train the community on efficient uses of electricity and, above all, to monitor consumption values to anticipate any unforeseen events.

The same could happen with electric stoves and kettles but with less probability. During the fieldwork, the inhabitants showed interest in continuing to cook with dry biomass even knowing the positive aspects of changing cooking methods (cleaner air in their homes, less pollution, and more efficient processes with less time demand).

5. CONCLUSIONS

This study reviews the state of the art on the identification of energy needs in communities that have not consumed electricity before and formalize the literature. The attributes for the load curve forecasting process were critically selected: a bottom-up method, with primary sources of information collected by surveys through interviews from household to household, with an hourly resolution for the load curve in a 5 years time frame with determinist modeling. A new approach based on energy levels and type of consumers is introduced. It results in a significant time reduction in electrification projects. Typical load curves were tailored according to the local habits, equipment, and socioeconomic and demographic characteristics. The survey was applied to a case study and provided the required information for drawing the load curve successfully according to the objective defined.

The main results of the short survey show that the total electricity demand, including losses, reaches the value of 72.525,5 kWh/yr and it is distributed in the different sectors as follows: 45% households, 30% productive uses, 12% social and 13% anchor load. The different types of energy consumers are 7% low, 65% medium, 24% high, and 4% very high. The deterministic curve was turned into a stochastic and more realistic one. The max power pick was found to be 33 kW. The current monthly expenditure on energy is 5.56 USD/household.

The long survey makes it possible to characterize the community: status quo of electricity, demographics, socioeconomic, and dwelling. As the main result, there is a monthly WTP of 5 extra USD for electricity. Therefore, an estimated ATP of 10.56 USD/household per month. The survey and tool provide the inputs for a complete project design and feasibility analysis. It is also ready to perform sensitivity analyses and test other case studies.

To validate the methodology is necessary to do measurements of the power plant. It will be done as soon the electricity is available. The levels of energy and habits patterns can be redefined according to this measurement. Finally, whether or not this is the best way to determine energy needs through a load curve, we are confident that the best solution is the one that is co-designed with the community.

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Communication aligned with the Sustainable Development Objectives

Survey sample

Section 1: Households (required)

Household information	
• Id.number	66
• Name	J_____ R_____ P______
• Tel. number	+504 XXXXXX
• Coordinates	13°29'XX.XX"N; 87°13'XX.XX"O
Electrical appliances in 5 years	
• Lights + phone charging + radio (Tier1)	**Yes,** No
• Fan + TV (Tier2)	**Yes,** No
• Refrigerator and/or laundry machine (Tier3)	**Yes,** No
• Air cond. and/or microwave/e-kettle (Tier4)	Yes, **No**
• Others	
Habits	
• What time do you get up?	6:00 am
• Come back home to lunch?	11:00 am
• What time do you come back home?	18:00 pm
• What time do you go to sleep?	22:00 pm
Economical	
• Occupation	Employee, **Self-employed** **Agriculture**, Business, Commercial, Teacher, Other:
• Current energy expenditure per month [USD]	6 USD
• Income per month [USD]	100 USD
• ATP per month for energy [USD]	10 USD
Productive uses of electricity	
• Are you interested in starting a productive activity? Which one?	**Yes**, No Bar, Restaurant, **Shop**, Barber/hairdresser, Guesthouse, Sewing, Milling, Other:

Section 2: Households (necessary)

Status quo of electricity	
• Current energy use of electricity	**Phone charging**, **Lighting**, Cooking, Others:
• Solar home systems [W]	50 W
• Battery capacity [Ah and V]	12 V / 9 Ah
• Installed generator power [W or VA]	None
• Other energy source consumption ([l/month of diesel/kerosene])	None
Demographics	
• Years living in the community	55 years
• Gender	Female, **Male**, binary
• Marital status	**Married**, Single, Other
• Age	18-30, 30-45, **45-60**, >60
• Education level	**None**, Primary, Secondary, University, Other
• Children under 18	1, 2, 3, **4**, 5, 6, 7, 8
• Children attending to school	1, **2**, 3, 4, 5, 6, 7, 8
• Person/hh	1, 2, 3, 4, 5, **6**, 7, 8
Houses	
• Construction characteristics	Brick, **Crumbling concrete**, Concrete, Wood, Venner, Other
• Square meters approx	45 m^2
• Rooms in the home	5
• Sleeping rooms	3
• Ownership	**Own**, Rent, Other
Seasonality	
• Does income fluctuate seasonally?	25 USD low/ 125 USD high season
Willingness to pay	
• What is important to you?	**Cost**, Quality, Duration of electricity
• What most likely will drive you to connect?	Neighbors, **Own needs**, Low connection fee
• Will electricity improve your life/business?	**Yes**, No, Don't Know
• Electricity will be...	Free, **Commercial**
• Who will pay for the electricity?	**Myself**, My boss, Elders, Family, **Government**
• What percentage of your salary are you willing to spend on electricity?	< 5%, **5-10%**, 10-20%, 20-30%, > 30%
Mechanical/Transportation	
• Combustion vehicles	Car, Truck, Motorcycle, Other
• Active Mobility	**Walking**, Jogging, Cycling
• Animal forcé	Horse, Dunkey, Other

Section 3: Community Leader (required)

Community leader information	
• Lider Name	XXX, XXX XXX
• Tel. number	XXX XXX XXX
• Coordinates	XXX XXX
Agricultural servicies	**Quantities/ Power (W)/ operation timelapse**
• Mill	None
• Water pump	3 / 3000 W/ 11:00 to 15:00
• Others:	
Industrial	
Production of liqueurs or fermented beverages	None
Production of jams or preserves	None
Fruit dryer	None
Others	None
Social	
• School	1
• Church	1
• Healthcare facility	1
• Hall	1
• Others:	
Anchor load	
• Internet tower	1
• Others	

Load curve design for the different sectors (sample)

Hour ID	Households								
	Tier 1			Tier 2		Tier 3		Tier 4	
	Lamps	Charg	Radio	Fan	TV	Refri	Others	Split	Others
1	0	1	0	0	0	1	0	0	0
2	0	1	0	0	0	1	0	0	0
3	0	0	0	0	0	1	0	0	0
4	0	0	0	0	0	1	0	0	0
5	0	0	0	0	0	1	0	0	0
6	0	0	0	0	0	1	0	0	0
7	1	0	0	0	0	1	0	0	0
8	0	0	0	0	0	1	0	0	0
9	0	0	0	0	0	1	0	0	0
10	0	0	0	0	0	1	0	0	0
11	0	0	0	0	0	1	0	0	0
12	0	0	0	0	0	1	0	0	0
13	0	0	0	1	0	1	0	0	1
14	0	0	0	0	0	1	0	1	0
15	0	0	0	0	0	1	0	0	0
16	0	0	0	0	0	1	0	0	0
17	0	0	1	1	0	1	0	0	0
18	0	0	1	1	0	1	0	0	0
19	0	0	0	0	0	1	0	1	0
20	1	0	0	0	0	1	1	0	1
21	1	0	0	0	1	1	0	0	0
22	1	0	0	0	1	1	0	0	0
23	1	1	0	0	0	1	0	0	0
24	1	1	0	0	0	1	0	0	0
Total (Hs)	6	4	2	3	2	24	1	2	2
users	75	75	75	70	70	21	21	3	3
app/user	2	1	1	1	1	1	1	1	1
W/app	15	5	20	50	120	35	500	900	600
1	0,0	0,4	0,0	0,0	0,0	0,7	0,0	0,0	0,0
2	0,0	0,4	0,0	0,0	0,0	0,7	0,0	0,0	0,0
3	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,0	0,0
4	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,0	0,0
5	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,0	0,0
6	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,0	0,0
7	2,3	0,0	0,0	0,0	0,0	0,7	0,0	0,0	0,0
8	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,0	0,0
9	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,0	0,0
10	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,0	0,0
11	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,0	0,0
12	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,0	0,0
13	0,0	0,0	0,0	3,5	0,0	0,7	0,0	0,0	1,8
14	0,0	0,0	0,0	0,0	0,0	0,7	0,0	2,7	0,0
15	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,0	0,0
16	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,0	0,0
17	0,0	0,0	1,5	3,5	0,0	0,7	0,0	0,0	0,0
18	0,0	0,0	1,5	3,5	0,0	0,7	0,0	0,0	0,0
19	0,0	0,0	0,0	0,0	0,0	0,7	0,0	2,7	0,0
20	2,3	0,0	0,0	0,0	0,0	0,7	10,5	0,0	1,8
21	2,3	0,0	0,0	0,0	8,4	0,7	0,0	0,0	0,0
22	2,3	0,0	0,0	0,0	8,4	0,7	0,0	0,0	0,0
23	2,3	0,4	0,0	0,0	0,0	0,7	0,0	0,0	0,0
24	2,3	0,4	0,0	0,0	0,0	0,7	0,0	0,0	0,0
Total (kW)	13,5	1,5	3	10,5	16,8	17,64	10,5	5,4	3,6

Hour ID	Productive Use										
	Restaurant			Bar			Shop			Barber	Water
	Refri	TV	Lamps	Refri	TV	Lamps	Refri	Lamps	Radio	Lamps	Pump
1	1	0	0	1	0	0	1	0	0	0	0
2	1	0	0	1	0	0	1	0	0	0	0
3	1	0	0	1	0	0	1	0	0	0	0
4	1	0	0	1	0	0	1	0	0	0	0
5	1	0	0	1	0	0	1	0	0	0	0
6	1	0	0	1	0	0	1	0	0	0	0
7	1	0	0	1	0	0	1	0	0	0	0
8	1	0	0	1	0	0	1	0	0	0	0
9	1	1	0	1	0	0	1	0	1	0	0
10	1	1	0	1	0	0	1	0	1	0	0
11	1	1	0	1	0	0	1	0	1	0	1
12	1	1	0	1	0	0	1	0	1	0	1
13	1	1	0	1	0	0	1	0	1	0	1
14	1	1	0	1	0	0	1	0	1	0	1
15	1	1	0	1	0	0	1	0	1	0	0
16	1	1	0	1	0	0	1	0	1	0	0
17	1	1	0	1	0	0	1	0	1	0	0
18	1	1	0	1	0	0	1	0	0	1	0
19	1	1	0	1	1	0	1	0	0	1	0
20	1	1	1	1	1	1	1	1	0	1	0
21	1	1	1	1	1	1	1	1	0	1	0
22	1	1	1	1	1	1	1	1	0	0	0
23	1	1	1	1	1	1	1	1	0	0	0
24	1	0	0	1	1	1	1	0	0	0	0
Total (Hs)	24	15	4	24	6	5	24	4	9	4	4
users	2	2	2	2	2	2	3	3	3	1	3
app/user	1	1	5	2	1	5	1	5	1	5	1
W/app	35	200	15	35	200	15	35	15	20	15	3000
1	0,1	0,0	0,0	0,1	0,0	0,0	0,1	0,0	0,0	0,0	0,0
2	0,1	0,0	0,0	0,1	0,0	0,0	0,1	0,0	0,0	0,0	0,0
3	0,1	0,0	0,0	0,1	0,0	0,0	0,1	0,0	0,0	0,0	0,0
4	0,1	0,0	0,0	0,1	0,0	0,0	0,1	0,0	0,0	0,0	0,0
5	0,1	0,0	0,0	0,1	0,0	0,0	0,1	0,0	0,0	0,0	0,0
6	0,1	0,0	0,0	0,1	0,0	0,0	0,1	0,0	0,0	0,0	0,0
7	0,1	0,0	0,0	0,1	0,0	0,0	0,1	0,0	0,0	0,0	0,0
8	0,1	0,0	0,0	0,1	0,0	0,0	0,1	0,0	0,0	0,0	0,0
9	0,1	0,4	0,0	0,1	0,0	0,0	0,1	0,0	0,1	0,0	0,0
10	0,1	0,4	0,0	0,1	0,0	0,0	0,1	0,0	0,1	0,0	0,0
11	0,1	0,4	0,0	0,1	0,0	0,0	0,1	0,0	0,1	0,0	9,0
12	0,1	0,4	0,0	0,1	0,0	0,0	0,1	0,0	0,1	0,0	9,0
13	0,1	0,4	0,0	0,1	0,0	0,0	0,1	0,0	0,1	0,0	9,0
14	0,1	0,4	0,0	0,1	0,0	0,0	0,1	0,0	0,1	0,0	9,0
15	0,1	0,4	0,0	0,1	0,0	0,0	0,1	0,0	0,1	0,0	0,0
16	0,1	0,4	0,0	0,1	0,0	0,0	0,1	0,0	0,1	0,0	0,0
17	0,1	0,4	0,0	0,1	0,0	0,0	0,1	0,0	0,1	0,0	0,0
18	0,1	0,4	0,0	0,1	0,0	0,0	0,1	0,0	0,0	0,1	0,0
19	0,1	0,4	0,0	0,1	0,4	0,0	0,1	0,0	0,0	0,1	0,0
20	0,1	0,4	0,2	0,1	0,4	0,2	0,1	0,2	0,0	0,1	0,0
21	0,1	0,4	0,2	0,1	0,4	0,2	0,1	0,2	0,0	0,1	0,0
22	0,1	0,4	0,2	0,1	0,4	0,2	0,1	0,2	0,0	0,0	0,0
23	0,1	0,4	0,2	0,1	0,4	0,2	0,1	0,2	0,0	0,0	0,0
24	0,1	0,0	0,0	0,1	0,4	0,2	0,1	0,0	0,0	0,0	0,0
Total (kW)	1,68	6	0,6	3,36	2,4	0,75	2,52	0,9	0,54	0,3	36

Hour ID	Social Infrastructure												Anchor
	School					Street	Church	Health care		Hall			Load
	Lamps	Printer	Comp	Fan	Router	Lamps	Lamps	Refri	Lamps	Lamps	Fan	Comp	Tower
1	0	0	0	0	1	1	0	1	0	0	0	0	1
2	0	0	0	0	1	1	0	1	0	0	0	0	1
3	0	0	0	0	1	1	0	1	0	0	0	0	1
4	0	0	0	0	1	1	0	1	0	0	0	0	1
5	0	0	0	0	1	1	0	1	0	0	0	0	1
6	0	0	0	0	1	1	0	1	0	0	0	0	1
7	0	0	0	0	1	1	0	1	0	0	0	0	1
8	0	0	0	0	1	0	1	1	1	0	0	0	1
9	1	1	1	1	1	0	1	1	1	1	0	1	1
10	1	0	1	1	1	0	1	1	1	1	0	1	1
11	1	0	1	1	1	0	1	1	1	1	1	1	1
12	1	0	1	1	1	0	1	1	1	1	1	1	1
13	1	0	1	1	1	0	1	1	1	1	1	1	1
14	1	0	1	1	1	0	1	1	1	1	1	1	1
15	1	1	1	1	1	0	1	1	1	1	1	0	1
16	0	0	0	0	1	0	1	1	1	1	0	0	1
17	0	0	0	0	1	0	1	1	1	1	0	0	1
18	0	0	0	0	1	0	1	1	1	1	0	0	1
19	0	0	0	0	1	1	1	1	1	0	0	0	1
20	0	0	0	0	1	1	1	1	1	0	0	0	1
21	0	0	0	0	1	1	1	1	1	0	0	0	1
22	0	0	0	0	1	1	1	1	1	0	0	0	1
23	0	0	0	0	1	1	0	1	1	0	0	0	1
24	0	0	0	0	1	1	0	1	1	0	0	0	1
Total (Hs)	7	2	7	7	24	13	15	24	17	10	5	6	24
users	1	1	1	1	1	1	1	1	1	1	1	1	1
app/user	6	1	10	1	1	20	5	1	5	5	1	1	1
W/app	15	500	15	50	6	50	15	35	15	15	50	200	1
1	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0
2	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0
3	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0
4	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0
5	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0
6	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0
7	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0
8	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,1	0,0	0,0	0,0	1,0
9	0,1	0,5	0,2	0,1	0,0	0,0	0,1	0,0	0,1	0,1	0,0	0,2	1,0
10	0,1	0,0	0,2	0,1	0,0	0,0	0,1	0,0	0,1	0,1	0,0	0,2	1,0
11	0,1	0,0	0,2	0,1	0,0	0,0	0,1	0,0	0,1	0,1	0,1	0,2	1,0
12	0,1	0,0	0,2	0,1	0,0	0,0	0,1	0,0	0,1	0,1	0,1	0,2	1,0
13	0,1	0,0	0,2	0,1	0,0	0,0	0,1	0,0	0,1	0,1	0,1	0,2	1,0
14	0,1	0,0	0,2	0,1	0,0	0,0	0,1	0,0	0,1	0,1	0,1	0,2	1,0
15	0,1	0,5	0,2	0,1	0,0	0,0	0,1	0,0	0,1	0,1	0,1	0,0	1,0
16	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,1	0,1	0,0	0,0	1,0
17	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,1	0,1	0,0	0,0	1,0
18	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,1	0,1	0,0	0,0	1,0
19	0,0	0,0	0,0	0,0	0,0	1,0	0,1	0,0	0,1	0,0	0,0	0,0	1,0
20	0,0	0,0	0,0	0,0	0,0	1,0	0,1	0,0	0,1	0,0	0,0	0,0	1,0
21	0,0	0,0	0,0	0,0	0,0	1,0	0,1	0,0	0,1	0,0	0,0	0,0	1,0
22	0,0	0,0	0,0	0,0	0,0	1,0	0,1	0,0	0,1	0,0	0,0	0,0	1,0
23	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,1	0,0	0,0	0,0	1,0
24	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,1	0,0	0,0	0,0	1,0
Total (kW)	0,63	1	1,05	0,35	0,144	13	1,125	0,84	1,275	0,75	0,25	1,2	24