International Journal of Emerging Trends in Engineering and Basic Sciences (IJEEBS)
ISSN (Online) 2349-6967
Volume 7, Special Issue 2 (March-April 2020), PP. 303-312

Digital Interface for Real-Time Monitoring of Electrical Appliances for Reducing Electricity Wastage

Ameya Shahu[1], Gauri Toshniwal[2], Prabhdeep Singh Sethi[3], Saurabh Somkuwar[4]

[1,2,3,4]Department of Computer Science & Engineering, Government College of Engineering, MIHAN Rehabilitation Colony, Nagpur, Maharashtra, India

Abstract: Metricity is a digital interface that provides real-time monitoring of electrical appliances. Conventional meters cannot monitor consumption of electrical appliances in real-time. Smart meters provide real-time utilization but not at the device/appliance level. This major problem in Indian households creates trust issues between the consumers and power suppliers thereby advocating for a cross-checking platform. Electricity theft is also a pressing issue in India. Moreover, electrical wastage is a challenge that not only squanders money and resources but also creates a fatalistic environmental impact. Metricity is a one-stop solution to all these problems. Metricity delivers device-level monitoring that is cumulatively equal to the electricity bill and also helps detect anomalies in the bill. Besides providing cross-checking, it also makes users aware of possible thefts by exposing mismatches found in the bill after comparing it with smart meter readings. Providing real-time utilization details reduces overall consumption by 10-15% which then helps to combat overconsumption, minimize electrical wastage, and reduce the carbon footprint.

Keywords: real-time monitoring, cross-checking platform, appliance level monitoring, smart electric meters, reducing electrical wastage

1. Introduction

1.1 Overview - Problems with India's electrical infrastructure:

India is the third-largest producer as well as the third-largest consumer of electricity in the world. It has an installed capacity of 368.79 GW and an electrical coverage of 99.7%. Despite this overwhelming potential India has never come close to actually utilizing it. The electricity sector in India, right from distribution to consumption, remains inefficient and underutilized.

The country has surplus power generation capacity but lacks adequate distribution infrastructure. Moreover, the per capita electricity consumption is low compared to most other countries despite India having a low electricity tariff. The issues under both distribution and consumption are grave and endless owing to India's primitive facility and mindset. This paper specifically focusses on suggesting measures to make the process of electricity consumption more efficient by real-time monitoring of consumption.

1.2 Nature of the problem and issues with efficiency:

India reported transmission and distribution losses of 21.04% in 2017-18 which when combined with consumer-level losses easily cross 30%. Add to this excessive expenditure, massive electrical wastage, inadequate connectivity, unreliable distribution, and erratic pricing. No wonder why most Indians are always found whining and grumbling about their electricity bills. These consumers also find themselves helpless and cannot really do much to change the sorry state of affairs. The Indian consumer lacks data-driven control over his own electrical consumption. He has no way of monitoring his electrical usage in real-time. The majority of Indian households still operate on conventional meters which do not allow real-time monitoring of daily electricity consumption. There is no tangible effective method to monitor and measure and hence to optimize the performance of any appliance. An average Indian consumer when bestowed with such control and monitoring facilities over his electrical consumption will be able to manage it more effectively. Not only will it make him aware of the excessive expenditure but will also help in reducing costs.

Another glaring issue denting the whole concept of electrical efficiency in India is the theft of electricity. The country loses $16.2 billion annually due to electricity theft. Its consequences on the GDP are unimaginable. Real-time monitoring of electrical appliances has the ability to mitigate the losses due to electrical theft if implemented in India. The issue is highly alarming because India loses more to theft than any other country in the world. Mumbai alone loses $ 2.8 billion annually which is more than the combined total of eight other countries.

1.3 Significance of real-time monitoring:

It is imperative to expand and enhance the infrastructure and consumption scenario in India. It is necessary to plug the holes and to make the process efficient. Real-time monitoring of electrical appliances could just be the key to it. It would help optimize consumption and will deliver data-driven results. This technology would help the users in making updated informed decisions and analyze trends as they develop. Moreover, it would massively benefit the two largest sectors of consumption in India – industry (41.16%) and households (24.76%) by reducing electrical wastage and expenditure.

It should be noted that any innovative measure in this sector needs to be sustainable and flexible. Care should be taken not to disrupt the already existing humongous infrastructure. Therefore, real-time monitoring if brought into practice, should be implemented using wireless networks, digital and smart technological measures, IoT equipment, and ad-hoc infrastructure.

1.4 Purpose:

Real-time monitoring will ensure that every type of consumer understands his consumption before paying for it. Analyzing and understanding this consumption are the basic steps towards reducing electrical usage and eventually saving electricity. But it is important to be carried out at the most granular level of usage. It is only when the process is decentralized that the users will be able to take control of their daily consumption and ultimately cut costs. Monitoring holds the complete potential to first minimize economic losses and then eventually accelerate economic growth. Reportedly, real-time monitoring of electrical consumption can positively impact India's GDP by 1.5% when leveraged across domestic, industrial, commercial, and agricultural sectors.

The goal of electrical efficiency will be closer to reality when aided with real-time monitoring. Monitoring is the key to identifying areas where consumption can be reduced. Facilities such as hospitals, public buildings, shopping malls will benefit the most from continuous monitoring of electricity. The whole process will transform into a measurable and reliable entity. It would help India realize its complete potential.

1.5 Contribution of the Paper:

The paper proposes a solution that focusses on real-time monitoring of electrical appliances to reduce electrical wastage and excessive expenditure. It grants the user with data-driven control over his consumption and also helps curb the theft of electricity. The research is specific for appliances in India where conventional meters do not come equipped with real-time monitoring and where smart meters are extremely scanty in number.

The rest of the paper is organized as follows: Section 2 gives a statement of problem or a hypothesis that the paper will address, Section 3 describes the proposed solution and its technical aspects, and Section 4 describes the experimentation done to verify the workability of the proposed solution. The results from experiments have been presented in Section 5 followed by Future Work. Conclusion forms the next section followed by References in the last.

2. PROBLEM STATEMENT

2.1 Statement of Problem:

Formulating a technological solution to provide real-time monitoring of electrical appliances by synchronizing smart meters and devices together, to provide data-driven control over consumption, and to reduce instances of excessive usage, electricity wastage and theft of electricity.

The solution will be designed in the form of a responsive, cross-platform application that serves as a reviewing platform for electrical consumption in India and leads to reduced costs.

2.2 Motivation:

A majority of Indian households lack real-time monitoring of daily electricity consumption. Also, there are no data insights available to analyze the amount of consumption made by a user. Consumers lack data-driven control over their electricity expenditure. Also, consumers don't have any cross checking platform which gives them a sense of assurance about their electricity bill, rather they have to completely rely on the data provided to them by electricity suppliers. A platform that syncs meters and devices is required to curb the problem. Moreover, no mechanism supports appliance-level monitoring on a daily basis to have exact information about the consumption of specific appliances. Given such control, a consumer may be able to manage device consumption more effectively which would ultimately lead to reduced costs. Studies show that when a consumer is provided with real-time consumption metrics they tend to consume 15% less electricity. This not only helps in reducing wastage of electricity but also reduces the carbon footprint.

3. WORK DONE AND SOLUTION

3.1 Proposed Solution:

The proposed technical solution is a digitally responsive, cross-platform interface named Metricity. The solution primarily aims to provide real-time monitoring of electrical appliances. This monitoring, besides delivering appliance-level analysis, will also cater to simultaneous overall consumption. The idea is to synchronize the smart electricity meter with appliances through a digital platform. The whole system will be bound by a Wi-Fi-connected ad-hoc network supported by IoT architecture and deployed on a reliable cloud platform. Once installed, Metricity will continuously monitor the synced electrical appliances to generate daily, weekly and monthly consumption reports. These reports will be aptly represented in the form of comprehendible visualizations and usage statistics that will aid a user in optimizing his electrical consumption. The reports will provide data-driven control to the user and make him aware of his unnecessary expenses. Metricity aims to deliver precisely synced results which will help identify anomalies in the process of unit calculation. These results will also detect instances of electrical wastage, over-consumption, and electricity theft. Once a user understands the pattern of his consumption from the reports generated by Metricity, he will be able to adjust the usage of appliances as per his requirement. Not only will this lead to reduced costs but it will also increase an average Indian consumer’s trust and reliability on the process. He will feel more secure and satisfied. Metricity will also alert users of possibilities of excessive usage in the future based on their consumption pattern using Machine Learning.

ISSN (Online) 2349-6967
Volume 7, Special Issue 2 (March-April 2020), PP. 303-312

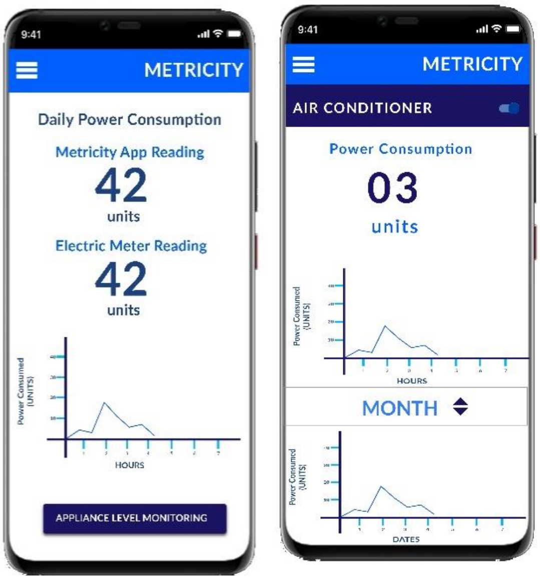

Fig. 1: Interface of the Proposed Solution

The world has been continuously talking about conservation of energy and new techniques are being devised to face an impending energy crisis. Given the crucial role that electrical energy plays in our lives, it is necessary to conserve it before time runs out. The situation grows grimmer when it comes to India because the country still produces a third of its total electricity from coal. Rather than waiting for the authorities to implement a massive conservation drive passing through each level of the electrical infrastructure, it is better to devise practices right at the consumer level that help this cause. Metricity finds its motive in a similar turn of events that help reduce electrical consumption, wastage, expenditure, and theft by real-time monitoring of appliances.

One common requirement for all smart and non-smart ecosystems will be a Smart Electric Meter for overall monitoring. Conventional meters possess typical problems that led to the conceptualization of Metricity. Smart Meter will be a quintessential requirement to achieve our objective. It will be most efficient when coupled with smart appliances because these devices will be readily connected in a single Wi-Fi network.

Fig. 2: Consumption of Appliances as seen in the application

But Metricity has been designed to respond to all types of devices irrespective of whether they are smart or not. The consumers will interact with a responsive user interface that responds to three types of environments – smart, semi-smart and non-smart. The application will be synced with a smart electricity meter and will measure device consumption using a microcontroller (for semi-smart and non-smart) or directly (for smart households). Metricity cross-checks consumption in real-time by comparing total device usage (units) summation with the actual meter reading thereby building a relationship of trust and also rectifying losses due to electrical theft.

3.2 Technical Aspects of the Proposed Solution:

The actual working of Metricity is distributed in three stages (Data Collection, Data Processing, and Delivery of results) and to understand it better consider the scenario of an average Indian household with commonly occurring electrical appliances. All these appliances will be connected to a microcontroller unit. The microcontroller unit will store timestamps of the events when each device was turned on/off thereby indicating the duration of consumption of the devices. In other words, the microcontroller will store the consumption data of all the appliances in the house (Data Collection). The stored data will then be sent to the server where a conversion factor would normalize these values to deliver actual usage of the appliance. A three-layered API built over the server which will manipulate the data according to the conversion logic to find out the power consumed by the appliances. The calculation for each device will be tailored according to its power consumption rate and capacity (Data Processing).

These results of consumption will then be delivered to the user as and when requested on the mobile interface. Visualizations will be employed to convey the results of consumption. They will appropriately describe trends, patterns, activities, and likely behaviour and will be friendly enough for the user to extract understandable insights. The predictions and alerts based on the consumption levels will also be part of the same process (Delivery of results).

The full-fledged implementation of Metricity will require a strong microcontroller for the appliances. It will also require relevant electronic components and IoT devices to create the desirable ad-hoc network. The hardware components will be programmed using C/C++ on the Arduino IDE. The hardware will be responsible for collecting data from the appliances which will then be stored and processed by a server built using Python in Flask. The server shall store, process, and retrieve this data from a cloud service which will also host the application. An MQTT broker will be responsible for setting protocol and exchanging information on the server-side. The cross-platform application will be designed using the Dart programming language in Flutter.

International Journal of Emerging Trends in Engineering and Basic Sciences (IJEEBS)
ISSN (Online) 2349-6967
Volume 7, Special Issue 2 (March-April 2020), PP. 303-312

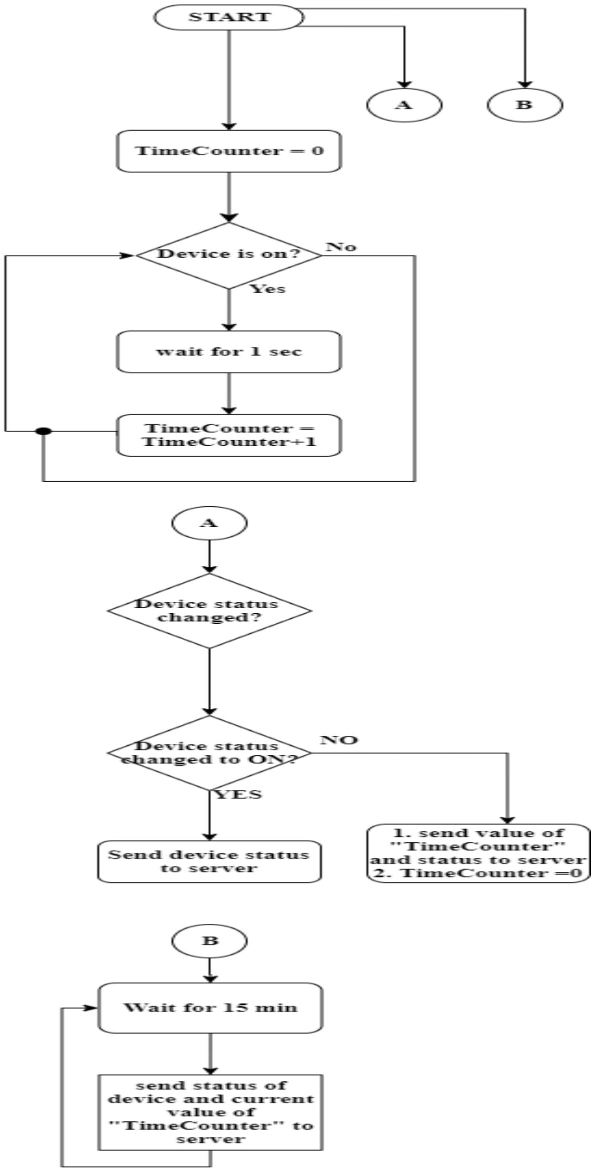

Fig. 3: Flow of operations

3.3 Novelty of Approach:

Metricity pioneers innovation by delivering precisely synced exact results from your smart electricity meters. Metricity makes innovative use of Smart IoT devices, Wi-Fi technology and Cloud to create an ad-hoc network of electrical appliances. It helps synchronize electrical meters creating a digital interface for consumption monitoring. This option wasn't present in other applications which were dependent only on algorithm-based predictions for generating those values. When used effectively, Metricity will prove useful not just for domestic consumers but also for power distribution companies. Such companies will be able to monitor the bulk of electrical supply and then regulate it using insights provided by Metricity. They are also the ones hit most hard by the theft of electricity – given the provisions of Metricity, they will be more equipped to tackle the situation. The issues in transmission and distribution of electricity can be potentially be solved if Metricity is properly scaled up through each echelon of the T & D infrastructure. It can help India achieve the efficiency that has always been talked about and just been talked about. The value propositions grow stronger as we are trying to convert every space whether domestic or commercial into a smart space. We are also providing Value Added Services (VAS) like device health monitoring, remote access (allowing a user to turn on or off the devices independent of their location) and also it is independent of whether the device is smart (IoT) or not. The proposition of making smarter switchboards in non-smart homes instead of all the devices will not just save money but will also fuel innovation. It also encompasses Data Science and Machine Learning to effectively use them for analysis, prediction, alerts, and recommendation.

Metricity has complete potential to be adopted in the current situation given the increased use of smart and energy-efficient devices. It is meant to keep a check on electrical consumption which is prone to good reception as conservation is the need of the hour. Also, it can prove as an essential requirement in the B2B sector as it is embracing modern and effective technologies. Though it may sound radical for domestic consumption but has a high possibility of being a quintessential requirement in the future.

4. METHODS AND MATERIALS

4.1 Experiment 1:

The prototype was designed to depict a simulation of an average Indian household with six electrical appliances. The idea was to test the power consumption of various appliances for a duration of 60 minutes. The six appliances were distributed in three rooms as below:

Drawing Room **-** Television, Light Bulb, Air Conditioner

Kitchen – Refrigerator, Light Bulb

Bedroom – Light Bulb

All the appliances are represented using LEDs and connected to ESP8266 (micro-controller). The time for which appliances are turned on is captured and displayed on Arduino IDE serial monitor.

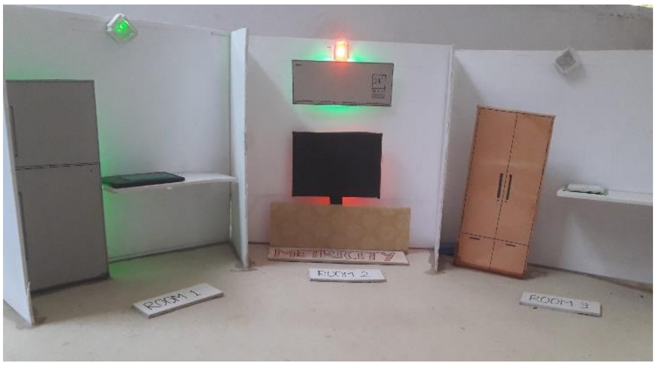

Fig. 4: Prototype for simulation

The unit consumption of each device has been normalized and stored by the micro-controller. Upon appropriate command, the appliances can be turned on/off. Once an

Appliance is switched on, the micro-controller starts measuring the electrical consumption made by it. The measurement ends when that appliance is turned off. The ESP 8266 records consumption in real-time when the devices are still in use. The consumption recorded in that interval of time is displayed as the value of units used by the appliance based on which the final reading is calculated. This reading is in normalized form catering to the appliances present in the prototype: tube lights, refrigerator, air conditioner and television. The same readings will be shown on Metricity's interface after the prototype is scaled.

International Journal of Emerging Trends in Engineering and Basic Sciences (IJEEBS)
ISSN (Online) 2349-6967
Volume 7, Special Issue 2 (March-April 2020), PP. 303-312

The standard average power rating of each appliance was considered for the experiment, which is as follows:

- Air-conditioner: 0.0003195 units/sec
- Light-bulb: 0.0000166 units/sec
- Television: 0.0000556 units/sec
- Refrigerator: 0.000112 units/sec

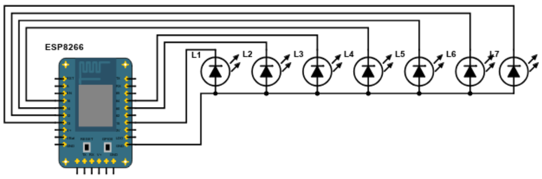

Fig. 5: Circuit Diagram for Experiment 1

These power ratings are multiplied by the duration for which a particular appliance was switched on to get the power consumption of that appliance.

4.2 Experiment 2:

The previous experiment provides a big picture about how our model works where all the appliances were represented using LEDs, so a CFL of 5 watt was used that operates on 50 Hz (220V -240V) to validate the above mentioned simulation.

The following gives a brief ideation of our experiment:ESP-8266 operates on 5V (DC) whereas the CFL mentioned above operates on 220V - 240V (AC) therefore a single channel relay module has been used to connect the CFL with the ESP8266.The Signal pin of relay has been connected with GPIO5 of ESP8266. The algorithm has been uploaded on ESP8266.

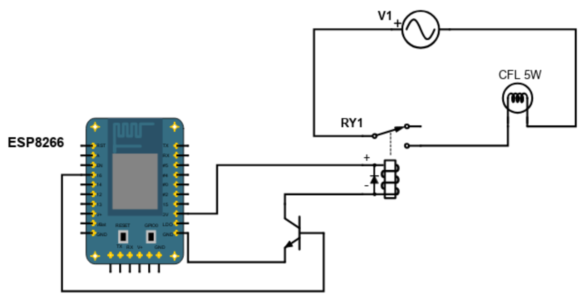

Fig. 6: Circuit Diagram for Experiment 2

5. DATA AND RESULTS

TABLE I: CONSUMPTION DATA 1

Sr. No.	Name of Appliance	Power Consumption (in units)(15 min)
1.	Refrigerator (Kitchen)	0.10248
2.	Light bulb (Kitchen)	0.01516
3.	Television (Drawing Room)	0.05099
4.	Air-Conditioner(Drawing Room)	0.10315
5.	Light Bulb (Drawing Room)	0.01526
6.	Light Bulb (Bedroom)	0.01512
	Total	0.30

The kitchen light bulb was turned off after 15 minutes.

TABLE II: CONSUMPTION DATA 2

Sr. No.	Name of Appliance	Power Consumption (units)(60 min)
1.	Refrigerator (Kitchen)	0.20619
2.	Light bulb (Kitchen)	0.01527
3.	Television (Drawing Room)	0.20389
4.	Air-Conditioner(Drawing Room)	0.41115
5.	Light Bulb (Drawing Room)	0.06091
6.	Light Bulb (Bedroom)	0.06007
	Total	1.85

The refrigerator was turned off after 30 minutes.

TABLE III:CONSUMPTION DATA 3

Sr. No.	Name of Appliance	Power Consumption (units)(30 min)
1.	Refrigerator (Kitchen)	0.20563
2.	Light bulb (Kitchen)	0.01527
3.	Television (Drawing Room)	0.10219
4.	Air-Conditioner(Drawing Room)	0.20630
5.	Light Bulb (Drawing Room)	0.03054
6.	Light Bulb (Bedroom)	0.03041
	Total	0.89

TABLE IV: DATA RECORDED FOR 5 W CFL

Timespan for which bulb is on (Minutes)	Power consumption (Units)
15	O.001251
30	0.002502
60	0.005003

6. FUTURE WORK

Metricity can improvise regressive predictions to send alerts on overconsumption.Based on consumption pattern, system will be able to tell whether device should be changed and if it is consuming more power for same time as it should ideally be.Blockchain based network can also be added so that users, Metricity, and electricity suppliers agree on the data.The product if scaled appropriately could be rolled out as a government scheme.

7. CONCLUSION

The concept of real-time monitoring was tested for 60 minutes on a prototype consisting of 6 appliances. Based on the experiments that have been conducted on the prototype, it was found that Metricity is able to calculate the consumption of each device. The readings were normalized for 6 LEDs, scaled to the actual consumption factor of the mentioned devices, and then reported on the serial monitor. To demonstrate the same with an actual appliance, a CFL bulb was used for experimentation. The experiments successfully demonstrated the working of Metricity's prototype which now awaits further expansion and proper scaling. These findings will prove useful in reducing domestic electrical consumption and will eventually lead to reduced costs by providing data-driven control. The presence of a Smart Electricity Meter is integral to the working of Metricity. It aims to deliver efficient results which might not be best achieved using conventional electric meters.

REFERENCES

[1] Kim, Woong & Lee, Sunyoung & Hwang, Jongwoon. (2011). Real-time Energy Monitoring and Controlling System based on ZigBee Sensor Networks. Procedia CS. 5. 794-797. 10.1016/j.procs.2011.07.108.

[2] Ruzzelli, Antonio & Nicolas, C. & Schoofs, Anthony & O'Hare, Gregory. (2010). Real-Time Recognition and Profiling of Appliances through a Single Electricity Sensor. IEEE SECON. 1 - 9. 10.1109/SECON.2010.5508244.

[3] Nader, Wisam. (2011). REAL-TIME POWER MONITORING, HOME AUTOMATION AND SUSTAINABILITY.

[4] M. A. Alahmad, P. G. Wheeler, A. Schwer, J. Eiden and A. Brumbaugh, "A Comparative Study of Three Feedback Devices for Residential Real-Time Energy Monitoring," in IEEE Transactions on Industrial Electronics, vol. 59, no. 4, pp. 2002-2013, April 2012.

[5] ESP Documentation: https://www.espressif.com/sites/default/files/documentation/0a-esp8266ex_datasheet_en.pdf.

[6] Wikipedia contributors. (2020, February 11). Electricity sector in India. In *Wikipedia, The Free Encyclopedia*. Retrieved 18:12, February 12, 2020, from https://en.wikipedia.org/w/index.php?title=Electricity_sector_in_India&oldid=940195857

[7] Wikipedia contributors. (2019, October 28). Theft of electricity. In *Wikipedia*, *The Free Encyclopedia*. Retrieved 18:13, February 12, 2020, from https://en.wikipedia.org/w/index.php?title=Theft_of_electricity&oldid=923435516