Enforcing Sustainability in Cities: The Case of Electricity Demand and Supply of Spain

Atif, M., Sattar, S., Amietszajew, T. & Bawany, M.

Original citation & hyperlink:
Atif, M, Sattar, S, Amietszajew, T & Bawany, M 2021, Enforcing Sustainability in Cities: The Case of Electricity Demand and Supply of Spain. in *2021 8th International Conference on Electrical and Electronics Engineering, ICEEE 2021*., 9415959, 2021 8th International Conference on Electrical and Electronics Engineering, ICEEE 2021, Institute of Electrical and Electronics Engineers Inc., pp. 132–135, 8th International Conference on Electrical and Electronics Engineering, ICEEE 2021, Antalya, Turkey, 9/04/21.
https://dx.doi.org/10.1109/ICEEE52452.2021.9415959

DOI 10.1109/ICEEE52452.2021.9415959
ISBN 978-1-6654-1161-5
ESSN 978-1-6654-4071-4

Publisher: IEEE

Enforcing Sustainability in Cities: The Case of Electricity Demand and Supply of Spain*

Muhammad Atif
Mechatronics Engineering
SZABIST
Karachi, Pakistan
m.atif@szabist.edu.pk

Saud Sattar
Institute of Future Transport and Cities
Coventry University
Coventry, United Kingdom
Sattars5@uni.coventry.ac.uk

Tazdin Amietszajew
Institute of Future Transport and Cities
Coventry University
Coventry, United Kingdom
taz.amietszajew@coventry.ac.uk

Muhammad Mehmood Bawany
Civil Engineering
NEDUET
Karachi, Pakistan
bawany3@gmail.com

***Abstract*—With the ever-increasing need for sustainability, energy efficiency is of growing importance. In this paper the analysis is conducted on a public dataset from Kaggle, which contains 4 years of electrical consumption, generation, pricing, and weather data for Spain. Different visualization techniques have been applied to estimate the pattern through which the sustainable demand and supply model can be generated for the country. The analysis showed that for the past 4-years the peak energy consuming hours in Spain are from 15:00 to 20:00 whereas from 00:00 to 05:00 in the morning, the energy consumption is minimal. Moreover, the results showed that in February energy consumption is at its peak whereas the minimum energy is consumed during the month of September. Such analysis could be used by governments to implement sustainable energy policy and adjust electricity storage and production based on statistics-driver prognosis.**

***Index Terms*—Energy Predictions, Sustainable Algorithms, Efficient System, Data Mining**

I. Introduction

Energy efficiency simply means using less energy in a smarter way to perform the same task [1], therefore eliminating energy waste. Energy efficiency brings a variety of benefits: reducing greenhouse gas emissions, reducing demand for energy imports, and lowering our costs on a household and economy-wide level. While renewable energy technologies also help accomplish these objectives, improving energy efficiency is the cheapest [2] and often the most immediate – way to reduce the use of fossil fuels. There are significant opportunities for efficiency improvements in every sector of the economy, whether it is commercial or residential dwellings, transportation, various industries or energy generation. The dataset analyzed herein contains 4 years of electrical consumption, generation, pricing, and weather data for Spain. Consumption and generation data were retrieved from ENTSOE, a public portal for Transmission Service Operator (TSO) data. Settlement prices were obtained from the Spanish TSO Red Electric España. Weather data was purchased as part of a personal project from the Open Weather API for the 5 largest cities in Spain and made public here. This dataset is unique as it contains hourly data for electrical consumption and the respective forecasts by the TSO for consumption and pricing. This allows prospective forecasts to be benchmarked against the current state of the art forecasts used in the industry.

The points listed below encompass the main energy efficiency factors.

A. Buildings

Architects are expected to optimize buildings energy efficiency and often incorporate renewable energy technologies, leading towards zero-energy buildings, so called passive houses. Adjustments to existing structures can also be made to reduce energy usage. These may include minor changes, such as choosing LED light bulbs and energy efficient appliances, or larger efforts such as upgrading insulation and weatherization [3] [4].

B. Energy Generation and Distribution

Combined heat and power systems capture the ”waste” heat from power plants and use it to provide heating, cooling, and/or hot water to nearby buildings and facilities. This increases the energy efficiency of power generation from approximately 33percent up to 80percent. The smart grid is another system that will improve the efficiency of electric generation, distribution, and consumption [5] [6].

C. Community Design

Neighborhoods that are designed with mixed use developments and safe, accessible options for walking, biking, and public transportation are key to reducing the need for personal vehicle travel [7] [8].

D. Vehicles

More energy efficient vehicles require less fuel to cover a given distance. This generates fewer emissions and makes them significantly less expensive to operate. Plug-in hybrids and fully electric vehicles are particularly fuel efficient [9] [10].

E. Freight

Freight can be moved more efficiently by improving the efficiency of rail and truck transportation and by shifting long-distance freight transport from trucks to rail [11] [12].

F. Human Behavior

The four strategies above improve energy efficiency primarily through technology and design. However, the way people use these technologies will significantly impact their effectiveness. What impact can a highly efficient technology have if households and businesses are not motivated to buy, install, and/or activate it? How does driving behavior and unnecessary idling impact gas mileage? How many people will use public transportation if there is a cultural stigma against it? Research has shown that 30 percent of the potential energy savings of high efficiency technologies is lost due to a variety of social, cultural, and economic factors. Addressing these factors is also an important component of making our economy more energy efficient [13] [14].

The objective of this work is to identify the season/month, day and hour of a day in which maximum energy is consumed so that alternate measures could be taken to preserve energy. The dataset based on a 4 year long hourly tracking of energy consumption to identify the attributes of maximum and minimum energy consumption season. Such analysis can be utilized to optimize energy storage and generation plan and inform green energy policies, increasing overall system efficiency and reducing greenhouse gas emissions.

II. Methodology

To fulfill the objectives, various data visualization techniques have been applied on the given dataset in order to predict and identify the desired result. The process that we will follow throughout this analysis can be seen in Fig 1.

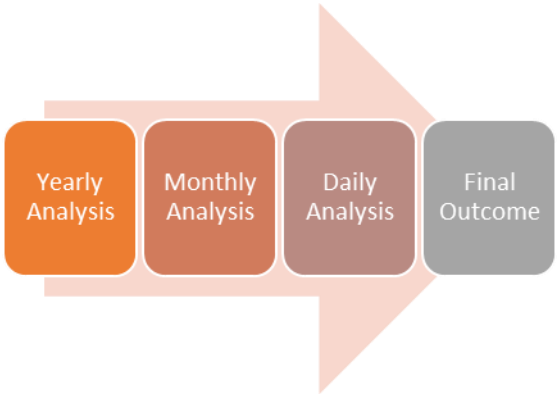

Fig. 1: Analysis process flowchart

A. Yearly Analysis

For better visualization, data is first broken into yearly sections that will help in identifying the hour of the day in which maximum energy is consumed, as shown in Fig. 2. The hours of the years are taken in commutative manner, i.e. one year contains 8760hrs, so that it could be identified that in which quadrant of year the energy consumption increases or decreases. Similarly, it is essential to identify at which hour of the day is most of the energy consumed. For this purpose mean yearly energy demand by hour of the day is plotted against the average energy consumption, shown in Fig. 3 the analysis of this curve showed that during early time of day energy consumption is minimal which gradually increases till 10:00 when people wakes up and start utilizing the appliances. After 10 a declination curve showed the people at work or grocery store where, routine energy is being consumed; however, most of the energy is consumed during the night time when people get back to their families and friends and enjoy the rest of the time with them, this is the peak time of energy consumption. Moreover, in electrical engineering, the most renowned parameter to determine the load consumption is load distribution curve that is plotted between the commutative hours of the year against the average power consumption. The load distribution curve is a very useful component as it helps in clear identification of season or month in which the maximum or minimum energy is consumed; although we aimed to determine the same thing through Fig 2 and Fig 3, however the load distribution curve simplifies the analysis and makes it visually understandable. The load distribution curve is shown in Fig 4.

B. Monthly Analysis

The yearlong analysis is further narrowed down up in this section for clarity and optimality. The commutative average consumption of each month is taken against the commutative hours, i.e., 720hrs (for the month of 30 days). This will help in identifying the month in which the most electricity is consumed. Furthermore, the same data is taken for the hour of day analysis against the month to get Mean monthly energy demand by the hour of the day. The resulting data is plotted in Fig 5. Similar to year, load distribution curve for monthly basis is also determined in order identify the optimized month Fig 7.

C. Daily Analysis

Daily analysis of electrical consumption is shown in Fig 6. This is done in order to determine the mean hour of the day in which the maximum amount of electricity is consumed.

III. Results Analysis

The above results are analyzed and interpreted in this section. As previously discussed, the main aim of this study is to determine the optimized season/month, day and hour of the day to get the optimized result of maximum and minimum energy consumption. The 3 shows that for the past 4-years the peak energy consuming hours are from 15:00 to 20:00 with the corresponding minimum at 00:00 to 05:00 in the morning. The load duration curve in Fig 4 shows that the energy consumption reaches maximum at the start of every year that is during the months of Jan, Feb and March due to hot summer days in Spain; whereas the trend sharply declines towards the end of year i.e., Sep, Oct, Nov and Dec the energy consumption is minimal due to cold and winter days. Fig 5 further clarifies that during the month of February from 15:00 to 20:00 the energy consumption is at its peak whereas the minimum energy consumption occurs during the

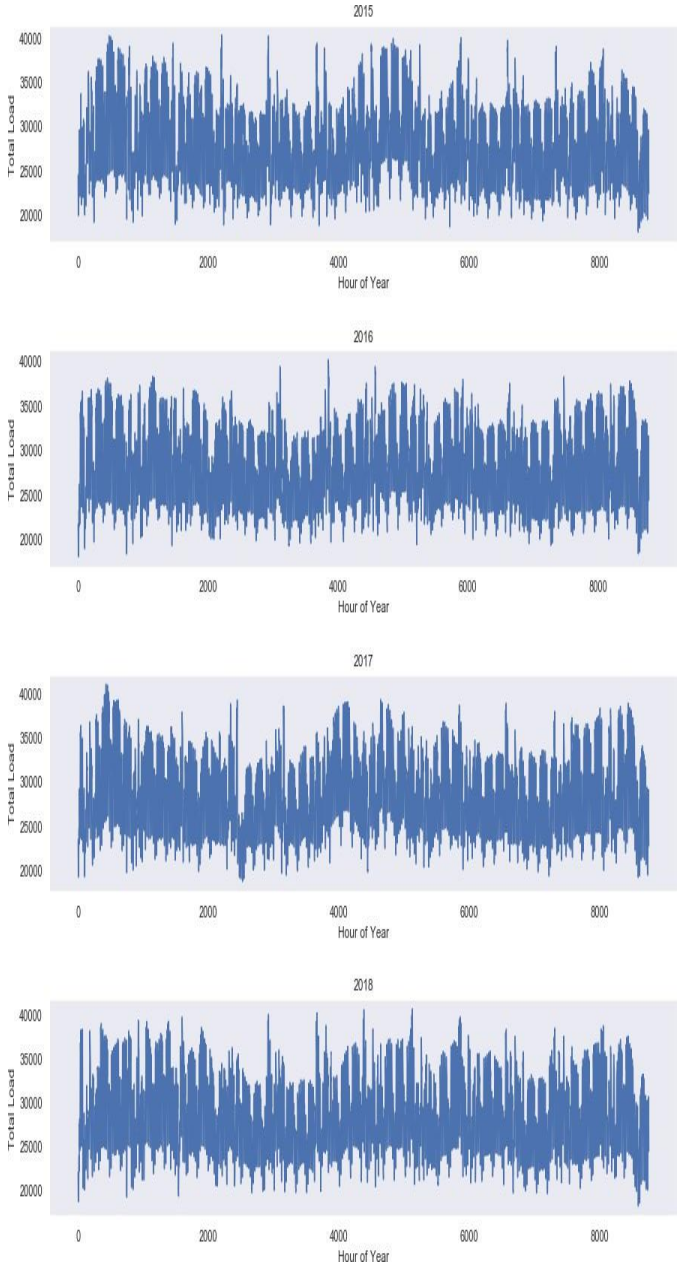

Fig. 2: Yearly energy consumption for 2015-2018

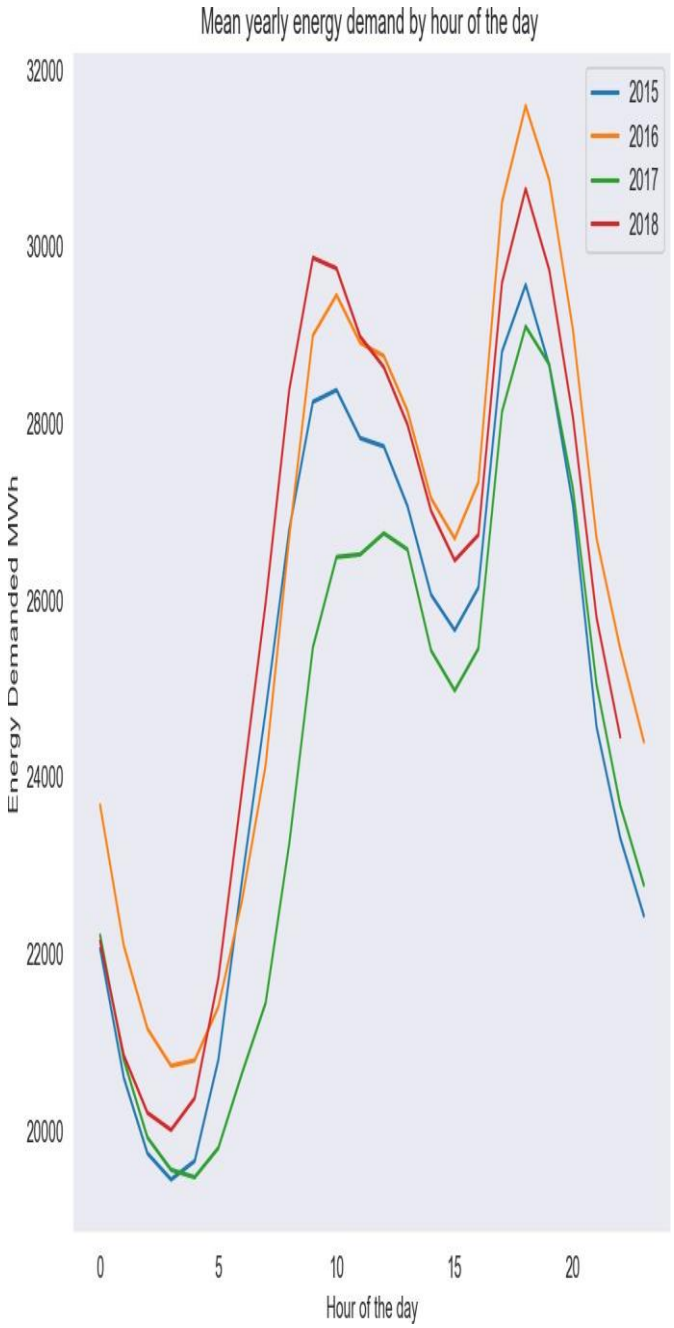

Fig. 3: Mean yearly energy demand by hour of the day (2015-2018)

month of September from 00:00 to 05:00. The load duration curve for months in Fig 7 shows that the energy consumption trend follows the same decline as that of each year. The consumption is at its peak at the start of month, whereas towards the end the consumption is minimal. Finally, Fig 6 shows that during the week, on Mondays from 15:00 to 20:00 the energy consumption is maximum whereas on Tuesday from 0000 to 0500 the opposite is true.

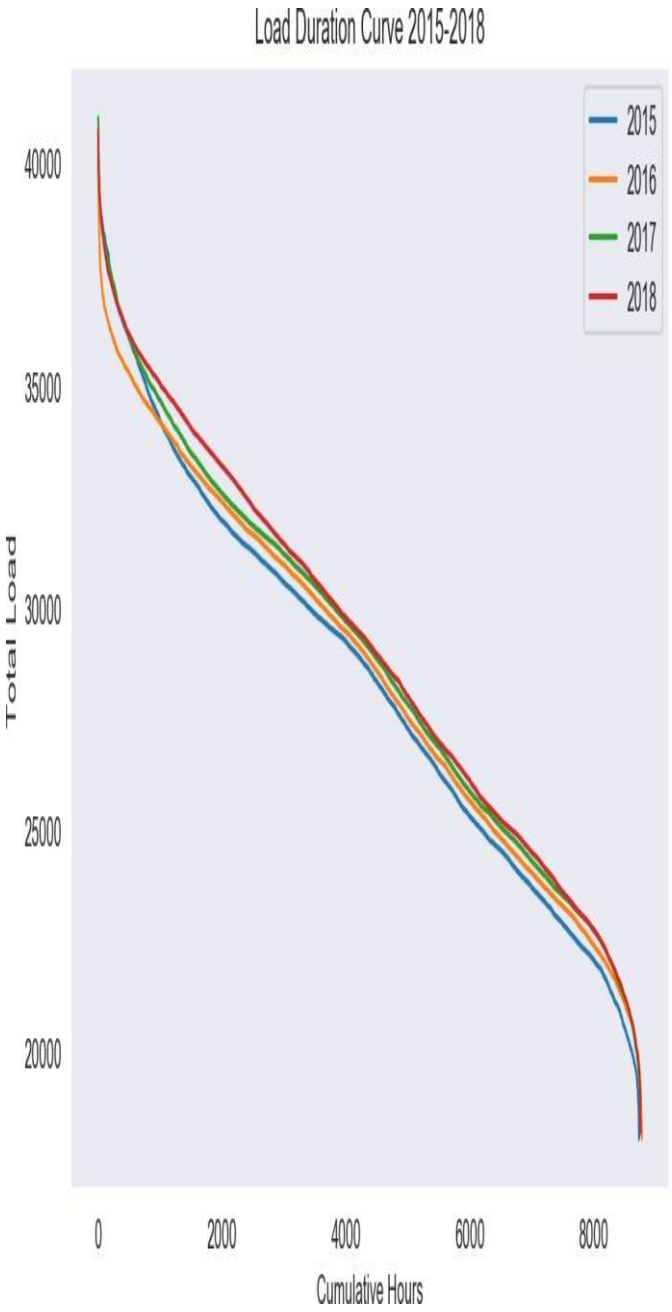

Fig. 4: Load Duration curve

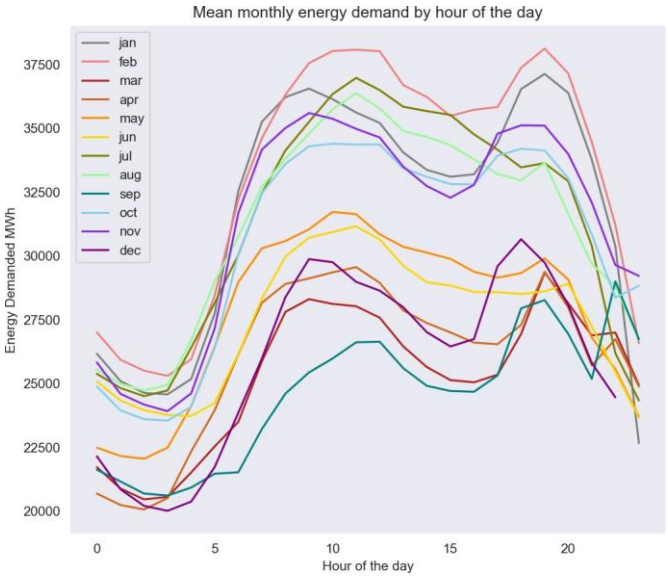

Fig. 5: Mean monthly energy demand by hour of the day, extracted from 2015-2018 datasets

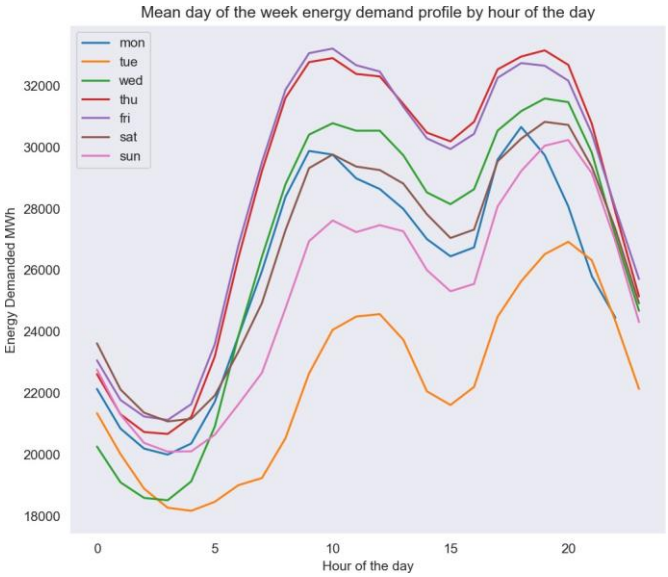

Fig. 6: Mean day of the week energy demand profile by hour of the day

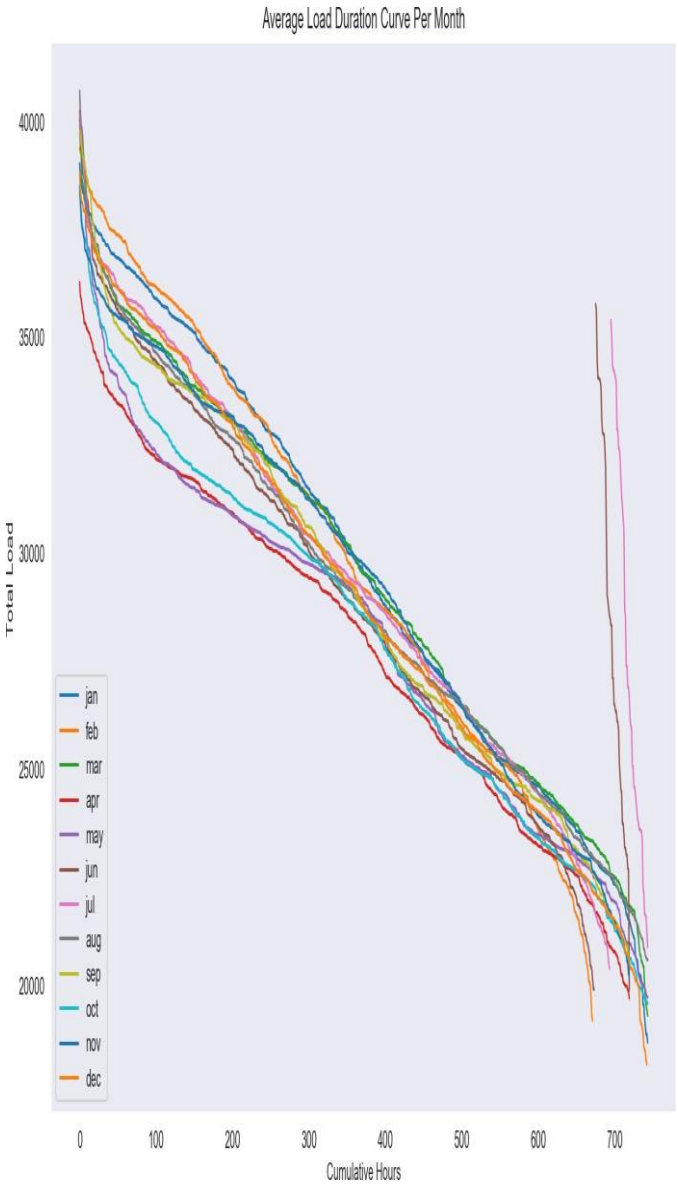

Fig. 7: Load Distribution Curves

IV. Conclusion

This report concludes that, based on the past 4 years of data, the maximum energy consumption in Spain falls on Mondays from 15:00 to 20:00 in the month of February. Whereas, on Tuesdays from 00:00 to 05:00 in Septembers the energy consumption is minimal. Based on this finding, the maximum energy budget should be included for the month of February as the consumption is at its maximum; subsequently, least amount of energy is required in Septembers.

On the basis of this analysis, it is recommended to adjust the energy policies keeping in mind findings from the statistical analysis. This will help sustainably consume expensive energy generated from sources like fossil fuels, in turn reducing carbon footprints and leadings to savings in the longer run.

Moreover, this analysis also encourages the extensive use of renewable energy, such as solar combined with energy storage. As the data shows, significant part of the electricity is utilized during night-time; this suggests renewable energy should be saved from the day-time to fulfill the night-time requirements. Therefore, government can take steps to harness the large amounts of solar energy available iduring the day and store it using the rapidly maturing energy storage technologies for convenient use at night.

Lastly, this report also shows that energy consumption is maximum in weekdays rather then at weekend, therefore activities such as updates or maintenance conducted on weekends would have the least impact on national grid and productivity.

References

[1] European Commission, “Next steps for a sustainable European future,” European action for sustainablity. 2016.
[2] P. Breeze, Power Generation Technologies. 2005.
[3] L. Pérez-Lombard, J. Ortiz, and C. Pout, “A review on buildings energy consumption information,” Energy Build., 2008.
[4] F. Junejo, A. Saeed, and S. Hameed, “5.19 Energy Management in Ocean Energy Systems,” in Comprehensive Energy Systems, Elsevier, 2018, pp. 778–807.
[5] S. Chowdhury, S. P. Chowdhury, and P. Crossley, Microgrids and active distribution networks. 2009.
[6] Office of Electric Transmission and Distribution, “Grid 2030: A national vision for electricity’s second 100 years,” Energy, 2003.
[7] International Energy Agency, “Key World Energy Statistics,” Statistics (Ber)., 2011.
[8] J. M. Carroll and M. B. Rosson, “Participatory design in community informatics,” Des. Stud., 2007.
[9] T. Energy, “Annual Energy Review,” 2010.
[10] European Association for Battery Electric Vehicles, “Energy consumption , CO2 emissions and other considerations related to Battery Electric Vehicles,” Energy, 2009.
[11] C. Ratti, N. Baker, and K. Steemers, “Energy consumption and urban texture,” Energy Build., 2005.
[12] M. E. Haque, Y. He, S. Elnikety, T. D. Nguyen, R. Bianchini, and K. S. McKinley, “Exploiting heterogeneity for tail latency and energy effiiciency,” in Proceedings of the Annual International Symposium on Microarchitecture, MICRO, 2017.
[13] U.S. Energy Information Administration (EIA), “International Energy Outlook 2017 Overview,” U.S. Energy Inf. Adm., 2017.
[14] H. Feldman and K. J. Friston, “Attention, uncertainty, and free-energy,” Front. Hum. Neurosci., 2010.