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Computations of Energy Efficiency Potential in Puerto Rico

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Abstract*— A project to establish Energy Efficiency (EE) as a system resource in Puerto Rico has been under development since 2010. The project would help create the environment to have at least one percent annual EE improvement the Island. An important task to accomplish the above objectives is to conduct a potential study in order to find attainable targets for EE. The first EE potential study has been completed for the case of the Island. This study will serve as a decision making and planning tool that will facilitate the inclusion of EE as a system resource and program implementation. To develop the EE potential study the team integrated Energy Information Administration residential, commercial and industrial data with local utility disaggregate data. Local environmental conditions were also integrated to the analysis. The EE potential study shows that annual EE improvement can reach 2.23%, considering technology availability. This would add up to 26.7% improvement in EE during the 12 years under study.

***Index Terms*— Energy Efficiency, Energy Efficiency Potential.**

I. INTRODUCTION

The Puerto Rico Energy Affairs Administration received a grant from the US Department of Energy, under program DE-FOA-0000251 in September 2010 to develop the project titled Integrated Process to Stimulate Energy Efficiency Programs in Puerto Rico. The project aims to establish Energy Efficiency (EE) as a system resource, and to create the environment, policies and programs to have at least one percent EE improvement from 2013 to 2025. An important task developed during the first year of the aforementioned project is a study of maximum energy efficiency potential available in Puerto Rico. By the definition in [1] a potential study is a quantitative analysis of the energy savings that exists, is cost-effective, or could be realized through implementation of EE programs and policies. The current energy efficiency potential study (EEPS) includes the Puerto Rico Electric Power Authority system, comprised of approximately 1.4 million clients. All electrical energy consuming sectors have been evaluated. The current study will be used as a policy design tool, and will demonstrate energy efficiency must be considered as a system resource. The objective of this EEPS is to create a decision making tool that helps including EE as a resource in our Energy Policy and that serves for design and planning EE programs. The type of EEPS that has been conducted through this work is defined as a Technical Potential in [1], although it has some characteristics of a cost-effective potential study as well. This means that potential is computed as the maximum amount of energy that can be displaced by EE, disregarding cost-effectiveness and social effects of such measures. The computed EE potential will be used as a baseline for cost-effectiveness and social effects analysis of the programs. In this paper a method to conduct the EEPS, developed by the research team at the University of Puerto Rico-Mayagüez, is been presented, along with the results from such a study.

II. CONSIDERATIONS FOR APPLICATION TO THE POTENTIAL STUDY

The following considerations, including local issues, have been taken into account to conduct the current EEPS. Also, the data sources used for the study are listed.

A. The audiences that have been taken into account for the study are primarily, policy makers and the utility, and secondarily, EE consultants and the general public.

B. The potential study considers the twelve (12) years beginning on 2013, using 2009 data as the baseline.

C. Secondary research data, as defined by [1], has been used due to lack of local data from the utility. The sources of data for this study are Energy Information Administration (EIA) energy use data for buildings, and disaggregated sales data from the Utility[2].

D. The data above has been adjusted for regions of more than 2000 cooling degree days (CDD) as per EIA data.

E. We have considered 1,300,000 family dwelling clients. With regards to Air Conditioning (A/C), low efficiency units (12kBtu/hr, 10 SEER) were replaced with high efficiency units (20 SEER) as the main EE measure. Other programs were evaluated for lighting, refrigeration and water heating, to replace low efficiency equipment in order to establish the technical potential for a reduction in energy use [3].

F. For the commercial sector the analysis considers 30% reduction on HVAC and lighting loads [4, 5]. Refrigeration and water heating will be considered in future studies before establishing a figure for attainable EE potential.

G. Half the industrial sector was considered for analysis, because some plants have been reducing energy consumption in recent years. The same analysis used for the commercial sector was applied, 30% reduction on HVAC and lighting. However, the highest average loads in industry are machine drives, with over 50% of the total consumption. With advanced controls, 20% reduction in machine energy use is attainable [6]. Since there are high turnover rates in industry we considered a 50% penetration with this option, therefore allowing for a 10% technical potential reduction in total machine drive consumption.

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III. COMPUTATION METHOD

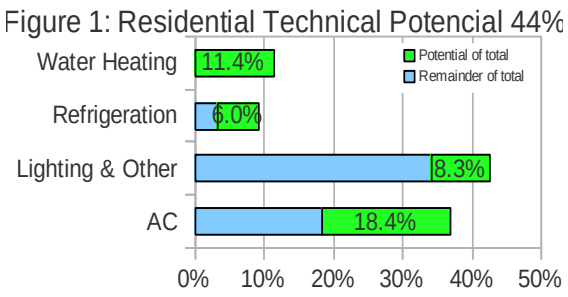
The following method was applied to the data available in order to perform the EEPS analysis.

1. Residential, commercial, and industrial data was gathered from EIA to have a baseline on energy use by different devices and appliances per sector [2].
2. The data in the previews step was regrouped into load types to consider energy consumption profiles that apply to the case of Puerto Rico.
3. An intermediate step was to apply environmental conditions so that the data is considered for regions of more than 2000 cooling degree days (CDD).
4. The results in step 3 were applied to the disaggregated sales data from the utility to have a characterization of local current energy usage by sector [2].
5. The data in the previous step was analyzed to find the areas of higher potential for EE in each sector.
6. EE measures applicable to Puerto Rico that were assumed in Section III above were applied to the data in step 5 for appropriate calculations.

General results projected to 12 years of study are presented in Table I. The aggregate EE potential may be approximately 26.7%, representing an improvement of 2.23% annually. The residential sector is having the highest potential, 15%, which suggests that Energy Policy must consider programs for this sector. The commercial sector, with a potential of 10.4% must also be consider in the Policy. The table also shows that the industrial sector may contribute an additional 1.3% at this point.

TABLE I: SUMMARY OF RESULTS FOR PUERTO RICO EEPS PROJECTED TO 12 YEARS FROM 2013 TO 2025.

Consumer Sector	EE Potential %
Residential	15.0
Commercial	10.4
Industrial	1.3
Total	26.7



IV. TECHNICAL EEPS RESULTS

This section presents the results of the EEPS in graphical format by consumer sector. Each figure shows the EE potential for each measure. The bars represent the percent of total energy consumption affected by the measure. In each bar the green shadow represents the EE potential, and the blue shadow represents the energy consumption after applying the measure. The percentage numbers shown in the bars are the EE potential for the type of load after applying such measure. In Figure 1 it is apparent that the highest potential exists in air conditioning (A/C), 18.4%, followed by water heating 11.4% and lighting 8.3%. In water heating specifically, the potential of 11.4% is assuming 100% of the water heating load for the residential sector. This is an important EE measure because the average sun hour radiation equivalent in Puerto Rico is approximately five (5) all the year. It has been shown that at least 80% of the water heating load can be supplied by the sun [7]. Considering all sectors this measure alone may reduce the generation capacity in Puerto Rico by 300MW. Advances in domestic AC technology (Inverter Technology) must also be applied since it has a very high EE potential for the residential sector. As shown in Figure 2, the commercial lighting has a high potential for EE with 13.1%, followed by HVAC 9.5%. In this sector only these two types of loads have been considered due to the total contribution the two have over the entire consumption. Lighting and HVAC alone account for more than 70% of the energy use in the commercial sector. Figure 3 & 4 shows the results for the industrial sector. This sector in Puerto Rico has the lowest potential of all, due to two

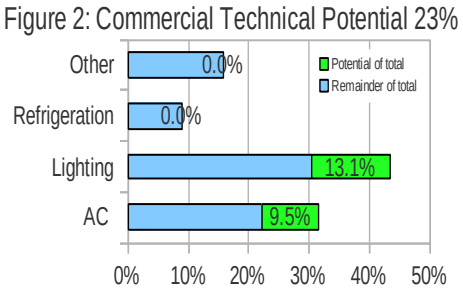


Fig2. Detailed Energy Efficiency Potential in the commercial sector.

factors. First, the elimination of section 936 of the US Internal Revenue Law, which allowed tax exemptions to US based companies with operations in Puerto Rico, resulted in a considerable migration and closures of many manufacturing plants. The second reason is that, based on interviews with some manufacturing companies, approximately half that sector of 900 clients is working towards EE at the moment. Cervecera de Puerto Rico is one interesting example of this EE movement in the industrial sector. The Cervecera de Puerto Rico brewery plant has reduced more than 40% in electricity demand and more than 50% in fuel consumption. Nevertheless, there is still a large potential for electrical demand reduction in machine drives with anticipated 5.1% potential that must be seriously considered as an important part of any EE plan for the Island, as shown in Figure 3.

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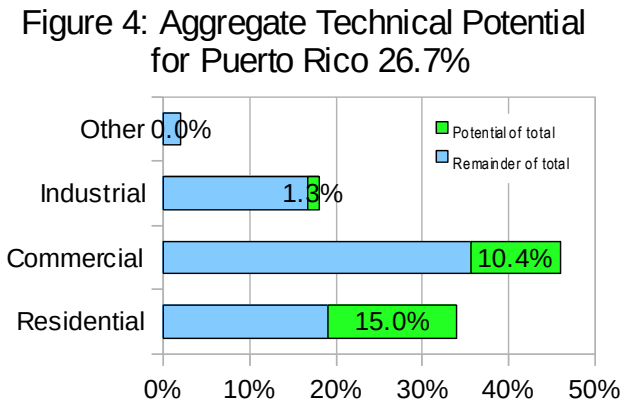

Fig 4. Total Aggregate Energy Efficiency Potential in Puerto Rico.

The total aggregate EE technical potential is presented in Figure 4, divided by the different consumer sectors. The residential sector in Puerto Rico is the one having the highest potential for EE, 15%, a number suggesting that any energy policy or other effort has to consider programs for this sector. The commercial sector, having a potential for an EE of 10.4% must also have to be consider in the energy policy. The figure shows that the contribution of the industrial sector at this point is 1.3% to the total potential reduction in energy use.

V. IMPACT OF THE PROGRAMS TO EFFECT EE

These EE potentials would be accomplished by availability of technology and funds. In order to accomplish the results above 130,000 residences and 13,000 businesses must be impacted yearly. This suggests that EE programs must be extremely aggressive to accomplish a target above 2% annually. Although technology exists, its availability implies physical, economic and social factors that must be taken into consideration for EE programs implementation. Social and implementation barriers are under consideration and will be presented in a future publication. The main factor affecting implementation of EE programs, as discussed in the previews paragraph, is the costs of replacing appliances in such a scale. Considering A/C and HVAC alone, annual costs of retrofitting such equipment approaches $340 million. With interests' rates between 4% and 5%, this adds to over $5 billion during the 12 years period. This compares favorably to implementing an equivalent 533MW power plant, with a cost of approximately $3 to $4 billion not including design and permits, operation and maintenance, health and environmental costs [8].

VI. CONCLUSION

The first EEPS has been completed for the case of Puerto Rico. This study will help to develop public Energy Policy and EE programs for the Island. In order to develop the EEPS residential, commercial and industrial EIS data with local utility disaggregate sales were used. Local environmental conditions were integrated to the data analysis also. The EEPS shows that the annual EE potential can be approximately 2.23% considering technology availability. This would account for 26.7% improvement in EE during the 12 years under study. This includes all residential, commercial and industrial sectors in Puerto Rico. Implementation of A/C and HVAC alone would cost in the neighborhood of $5 billion, which compares favorably with a power plant of approximately 500MW.

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REFERENCES

[1] National Action Plan for Energy Efficiency (2007), Guide for Conducting Energy Efficiency Potential Studies, Prepared by Philip Mosenthal and Jeffrey Loiter, Optimal Energy, Inc. (www.epa.gov/eeactionplan), pgs. 2-1, 2-4, 3-2.

[2] Data available from http://www.eia.gov/consumption/data.cfm; Data available from http://www.aeepr.com/estadisticas.asp.

[3] July 26, 2011: Saving Energy in Multifamily Buildings, available at http://www1.eere.energy.gov/buildings/webinar_archives.html #multifamily_bldgs_20110726.

[4] Strategies to Cut Energy Use by 50% in Commercial Buildings, http://www1.eere.energy.gov/buildings/webinar_archives.html #multifamily_bldgs_20110726.

[5] Commercial ReferenceBuildings — Benefits and Applications, http://www1.eere.energy.gov/buildings/webinar_archives.html #reference_20100518.

[6] B.C. Mecrow, A.G. Jack., "Efficiency trends in electric machines and drives", Energy Policy, 2008, vol. 36, issue 12, pages 4336-4341.

[7] J. Jiménez González, "Benefits of Electric Generation Displacement Using Solar Thermal Water Heaters", Master Thesis, University of Puerto Rico, Mayagüez, 2005.

[8] D. Anderson, "Electric System Impacts of Utility Large-Scale Investment in Building Energy Efficiency", 2011 ACEEE National Conference on Energy Efficiency as a Resource, Sep/2011, available at http://aceee.org/files/pdf/conferences/eer/2011/BS2C_Anderson.pdf.

AUTHOR'S PROFILE

Lionel R. Orama received his BSEE from the Polytechnic University of Puerto Rico, 1992. He conducted graduate studies at the Rensselaer Polytechnic Institute where he received a Master Degree 1994 and a Doctoral Degree in 1997. The title of his doctoral thesis is "Numerical Modeling of High Voltage Circuit Breaker Arcs and Their Interaction with the Power System". Dr. Orama joined the University of Puerto Rico in January, 1998. He does research in the areas of energy efficiency, renewable resources, electrical transients, power system protection, and teaches power and energy courses. Dr. Orama holds a Patent Pending on Maximum Power Point Tracking for PV arrays.

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