Using PAMS to estimate savings potential from increased energy efficiency – a case study

Ari Reeves and Ana Maria Carreño

CLASP

Abstract

What would you do if you had to estimate the energy savings potential from adopting energy efficiency policies for three household products in each of 33 countries, and had only two months to do it? The authors faced exactly this challenge in 2014.

For the task, the authors chose the Policy Analysis Modeling System (PAMS) [1], a free and publicly available impact model implemented in Microsoft Excel. PAMS was developed more than ten years ago by Lawrence Berkeley National Laboratory (LBNL) in collaboration with CLASP to provide first-order policy impacts projections with a minimum of preparatory research on the part of local policymakers.

PAMS comes pre-programmed with a host of inputs, including cost-efficiency curves and electricity prices, so users can identify the most cost-effective efficiency level to target with their policies. PAMS provides these inputs for three products—air conditioners, refrigerators, and clothes washers—for more than 100 countries. In the absence of reliable market data for a given country, PAMS can forecast the size of the market for a given product in that country based on climate and macroeconomic indicators such as household income.

Using PAMS, the authors estimated that the 33 countries of Latin America and the Caribbean (LAC region) could save a total of 137 TWh of electricity in 2030 if they adopted advanced energy efficiency standards for refrigerators, air conditioners, and ceiling fans by 2020. That is approximately 11% of current annual electricity use in the region.

This paper will describe how the authors customized and updated PAMS to suit the task at hand. Learn how PAMS was modified to analyze fans instead of clothes washers and to produce results for several small countries not included in the public version. Learn how the cost-efficiency curves and macroeconomic indicators were updated. The paper will also discuss how the authors used contemporary market data from several sources to improve the model's forecasts.

The paper will be of great value to the energy efficiency practitioner who is looking for an easy-to use yet sophisticated tool with which to estimate energy efficiency potential from product policies.

Introduction

The analysis described in this paper was developed in the framework of the Global Efficient Appliances and Equipment Partnership Programme, a public-private initiative led by the United Nations Environment Programme (UNEP), CLASP, the United Nations Development Programme (UNDP), the International Copper Association (ICA), and the Natural Resources Defense Council (NRDC) to accelerate the transition to more efficient appliances and equipment to reduce global energy demand, mitigate climate change, and improve access to energy.

This assessment aimed to highlight the opportunities in terms of energy and economic savings from a transition to energy efficient products in Latin American and the Caribbean (LAC) countries. Energy demand for cooling applications (such as refrigeration and air conditioning) is on the rise and expected to increase up to 61% between 2010 and 2030 in the absence of energy efficiency policies.[2] The economic and energy savings potential from adopting more efficient refrigerators, air conditioners and fans were analyzed in the LAC region: if the 33 countries adopt advanced energy efficiency standards for the three product categories, they could save 137 TWh of electricity in 2030, equivalent to 11% of current energy demand in the region.

Methodology

The team was tasked with analyzing economic and energy savings potential from a transition to more efficient appliances with limited time and resources for data collection. The analysis required the establishment of a base case for each appliance under the scope (or a base line considering an average product and its related energy consumption); definition of a policy case (or energy efficient option); relevant country data to characterize the electric sector (electricity rates, CO_2 emissions factors); and product market data to estimate present and future sales and stock. Considering that this process was taking place for three products in 33 economies, the team considered several available tools that would facilitate calculations (i.e., number of model runs) and would enable filling some of the data gaps through modeling.

Three appliance energy efficiency impact models were short listed, as they can be used to estimate the energy and greenhouse gas (GHG) impacts of improvements in market average product efficiency from the current year and up to 2030: the Bottom-Up Energy Analysis System (BUENAS), the Product Policy Analysis Tool (PPAT), and the Policy Analysis Modeling System (PAMS or PAMS-MEPS). The main characteristics of each model are summarized in the table below:

Table 1. Primary uses for and key characteristics of three appliance energy efficiency policy impact models

	BUENAS	PPAT	PAMS-MEPS
Primary Use	Sum energy savings potential across various products and 13 major economies	Compare and contrast energy savings potential across various products in a single economy	Find the most cost-effective efficiency level for a single product in a single economy
Key Points of Differentiation	Already contains market and efficiency data for various products and countries	User friendly Built-in data visualization tools Can estimate peak demand impacts	Can conduct the economic analyses needed to support policy development

In addition to the key points of differentiation above, there are major differences among the three models in the types of inputs, outputs, product and country coverage, and additional features. These are listed in the table below to facilitate comparison.

Table 2. Side-by-side comparison of three impact models

Model characteristics		BUENAS	PPAT	PAMS-MEPS
Purpose	Estimate Impacts (Energy and CO_2)	X	X	X
	Assess Ease of Policy Implementation		X	
	Compare Across Economies	X		
	Design Cost-Effective Policies			X
Scope	Economies	13 major economies	India only; extensible	150 countries
	Sectors	R, C, I[1]	R, C, I	R
	Products	More than 30	More than 30	Refrigerators, Room AC, clothes washers; extensible

[1] R: residential, C: Commercial, I: Industrial.

Model characteristics		BUENAS	PPAT	PAMS-MEPS
Fuels		Electricity, Natural Gas, Fuel Oil	Electricity, Fuel Oil, Gasoline, Kerosene	Electricity
Key Scenarios		BAU, Cost-Effective Savings, BAT[2]	BAU, Multiple User-Defined	BAU, MEPS (multiple levels)
Inputs	**Sales or Stock Time Series**	X	X	X
	Sales Growth Rate		X	
	Unit Energy Consumption	X	X	X
	Demand (Coincidence) Factor		X	
	Product Lifetime	X	X	X
	Product Prices			X
	Energy Prices	Optional		X
	Discount Rate	Optional		X
	Other Macroeconomic Variables	X		X
Outputs	**Stock (Each Year)**	X	X	X
	Sales (Each Year)	X	X	X
	Energy Demand (Consumption)	Final Energy[3]	X	Primary Energy[4]
	Electric Peak Power Demand		X	
	CO_2 Emissions	X	X	X
	Economic Impacts (National)			X
	Economic Impacts (Consumer)			X
Time Dimension	**Base Year for Market Data**	2005	2010*	2010*
	Policy Implementation Year	2015	=Base Year	2010*
	Time Horizon	2030	2030*	2030*
	Time Increment	1 year	5 years	1 year
Features	**Open Spreadsheet**			X
	Built-in Visualization Tool		X	X
	Can Assume Non-Zero Price Elasticity of Demand			X
	Can Assume Declining Product Prices (Learning)			X
	Can Assume Efficiency Improvement in BAU Case	X		X
Publicly Available				X

* The user can adjust this parameter as desired.

The PAMS model offered features that were advantageous in this assessment, mainly:

[2] BAU: business as usual, BAT: best available technology

[3] This quantity is also sometimes called “site” or “delivered” energy.

[4] This quantity is also sometimes called “source” energy.

- Macroeconomic data for economies under analysis are already available. The data already refers to possible sources of information and can be updated as required if more recent data becomes available. This can greatly reduce the time an analyst needs to compile data for multiple economies (i.e., 33 countries in this case).
- Built-in saturation functions to forecast appliance ownership levels for two of the appliances under analysis (refrigerators and air conditioners). These functions are especially helpful in economies where S&L are not yet in place and thus it is unlikely data will be available to characterize market sizes and growth.
- Ability to conduct cost-benefit analysis of potential policies.

There were three key disadvantages:

- PAMS does not have built-in household saturation parameters for fans
- PAMS cannot produce results for a series of products or countries simultaneously, in contrast to BUENAS and the PPAT, where all the inputs for each country and product are entered before running the model. This can increase the time to produce results, as each country-product combination must be run independently.
- Technology options to characterize the base case and policy scenarios are out of date.

A major constraint for the analysis was the lack of available market data for most of the 33 countries; thus the ability of PAMS to generate sales and stock forecasts based only on macroeconomic indicators was considered a major advantage, as was the ability to conduct cost-benefit analysis. The authors, therefore, chose PAMS for the task and made a number of updates and customizations to address the disadvantages of this model, as explained below.

Data collection, sources, and limitations

There are three types of data that need to be collected or defined as a minimum for this type of analysis:

1. *Country data* to define the energy sector and economic indexes of an economy
2. *Product market data* to characterize the market size and expected growth (both in terms of sales and stock)
3. *Energy use data*: includes the definition of the base case (current product energy performance) and the policy case (more efficient option)

The team made an effort to gather the most recent data for the three categories above in order to reduce the number of uncertainties and produce reasonable estimates, as required by the task at hand.

Updating *country data* was feasible due to the large number of available databases that track information such as population, household size, urbanization, and electrification rates. International organizations such as the UN, the World Bank and the IEA provide access to some of these data, with the advantage that reported data (for all economies) uses the same methodology for quantifying and reporting. Other relevant data to characterize the electricity sector in each economy, such as electricity prices and CO_2 emissions factors, were updated with information from country representatives. There might be some differences in these reported values, as methodologies to estimate average electricity prices or the CO_2 emissions factor vary by agency or by country.

Product market data were more difficult to collect as there is no single source or agency tracking sales in a consistent manner in the economies under scope. The team used mainly three sources of information in order to develop an understanding of the market and trends for each economy:

1. UN COMTRADE databases, which provides information on the number of units and monetary value of exports and imports by product and by country
2. Euromonitor International, a market research firm that collects sales data from a number of sources and provides historical and forecast sales figures for many products and countries
3. Manufacturer partners, who provided sales estimates for select countries and products

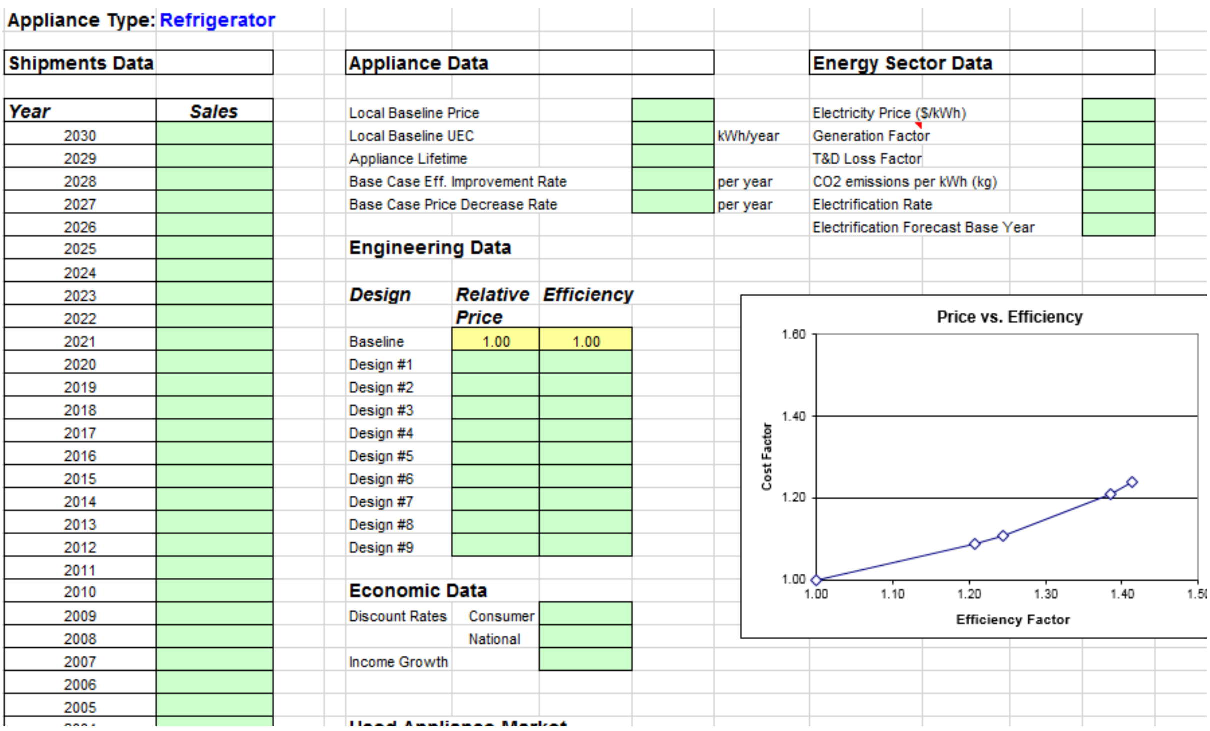
For each product-country combination, the authors triangulated between the available data sources, including the sales and stock forecasts PAMS produced using macroeconomic data. Each source has limitations. The COMTRADE database does not capture products produced domestically. The reliability of Euromonitor data varies from country to country and product to product, based mainly on the availability and reliability of underlying data sources. Data provided by manufacturers might not be representative of the whole market. Nevertheless, in the absence of a more reliable dataset, these data sources were used to put lower and upper bounds on sales and stock estimates obtained from PAMS, and to develop corresponding adjustments if necessary (i.e., if PAMS was significantly under- or over-estimating actual sales).

Energy use data is the most difficult category, as manufacturers are not required to report energy performance unless there is a standard and labeling (S&L) program in place requiring product registration. Since the task aimed to estimate potential energy savings from a policy scenario—a transition to more efficient appliances—a base case was selected that was representative of a market where S&L is already in place. In countries where there is no S&L in place, products are most likely less efficient and thus selecting a more efficient base case would yield lower energy savings. Thus, this was a conservative approach that would provide enough information for a country to decide whether or not an energy efficiency policy is necessary.

The selection of representative base cases and policy scenarios drew on data available from multiple sources. Important sources of such information included the technical support documents (TSD) developed by the US Department of Energy, which explain the technical analyses and results supporting the development of energy conservation standards, and the Preparatory Studies that provide technical evidence needed to draft implementing measures (i.e., minimum energy performance standards) under the Ecodesign Directive of the European Commission. The authors also made use of techno-economic analyses conducted by Lawrence Berkeley National Laboratory (LBNL) in support of the Super-efficient Equipment and Appliance Deployment (SEAD) Initiative. These documents provided extensive technical information on the energy performance and cost of products at various efficiency levels commercially available when those analyses were conducted.

The PAMS workbook includes a tab named “User Inputs,” which allows the user to override many of the preset input values. (See Figure 1.) The authors made liberal use of this capability. As discussed above, the shipment (or sales) time-series “default” values generated within PAMS needed to be adjusted in many cases in light of other available data. The adjusted values, once pasted into the User Inputs sheet, overrode the default values.

Figure 1. User inputs tab in PAMS which can be used to override default values

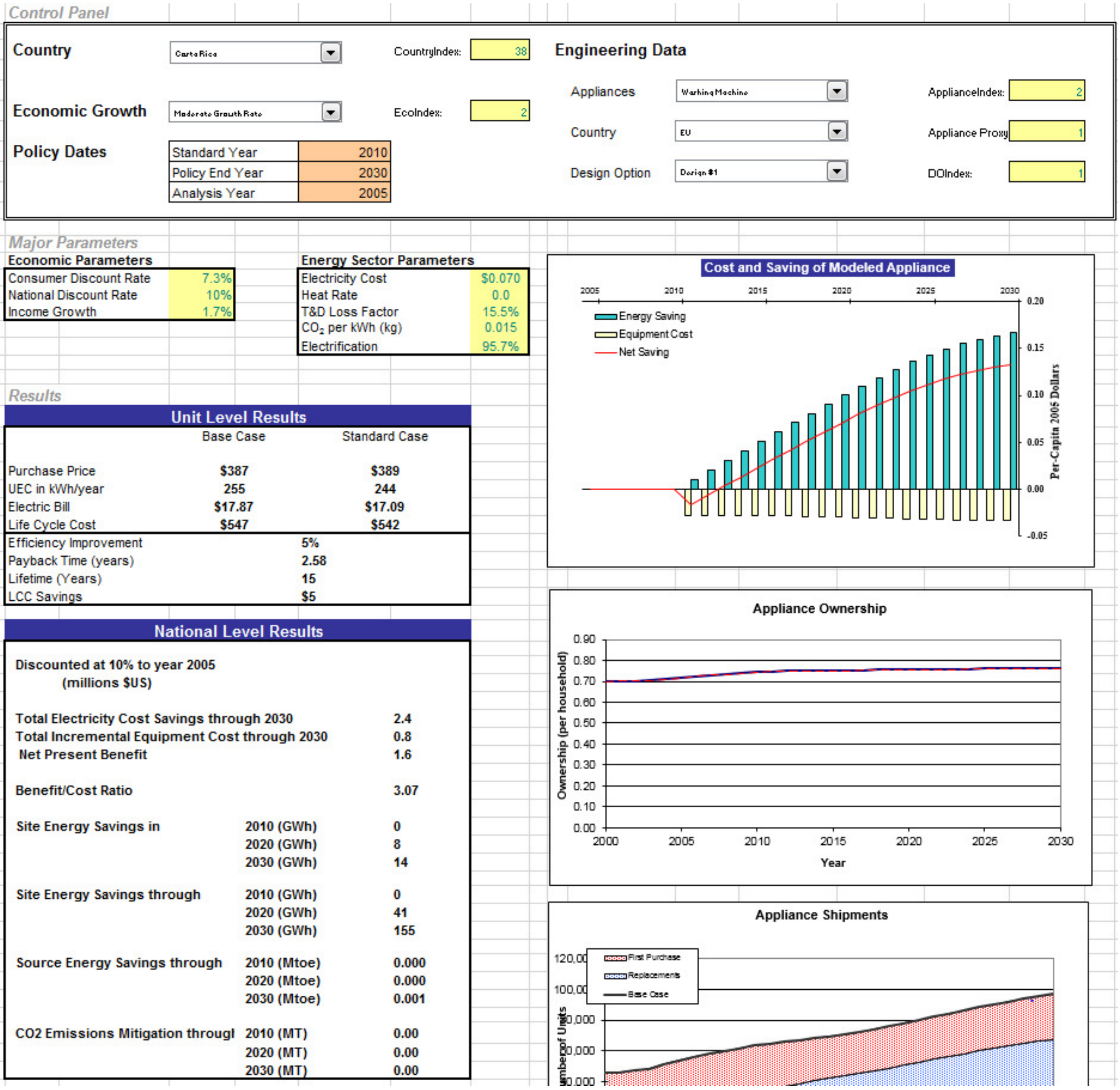


Limitations of the model

This section identifies specific limitations of PAMS and the customizations the authors implemented to overcome these limitations.

As mentioned earlier, PAMS produces results for one product in one country at a time. Figure 2 shows the tab that contains user controls, major input parameters, and summary results. The authors created a place within the workbook where all of the key outputs from a single model run were displayed in a single column. The values in that column could then be copied and pasted easily to another tab holding the results for all 99 model runs (3 products x 33 countries). PAMS does not offer a way to determine the efficiency level that minimizes consumer lifecycle cost. However, Excel's goal seeking function can be used for this purpose.

Figure 2. Summary tab in PAMS containing user controls and showing key results



The public version of PAMS contains formulas and coefficients for estimating household penetration levels for refrigerators, air conditioners, and washing machines, but not ceiling fans. The authors replaced the formula for washing machines in PAMS with the diffusion equation for ceiling fans specified in a study LBNL conducted for the SEAD Initiative [3].

Some of the 33 countries under study, generally the small island nations, are not included in the public version of PAMS. The authors first examined the original sources of country-specific data in PAMS to determine whether those sources contained data for the missing countries. If data were not available from those sources and other suitable sources could not be identified, similar countries were identified and used as proxies. Data for dozens of small countries in other regions of the world are also not included in PAMS.

PAMS contains a single electricity price for each country and offers no easy way to have this price change over time. For the analysis in question, a constant electricity price assumption was satisfactory, though other analysts may find this an important limitation of the model.

PAMS estimates both the site and source energy savings resulting from a transition to more efficient products. It does not, however, estimate peak demand savings. Such estimates were not required for the analysis in question. Crude estimates of demand savings can be obtained from the energy savings estimates assuming an annual average capacity factor. To get a more accurate picture of the relationship between improving the energy efficiency of a given product and the resultant effect on peak demand requires understanding when that product is used relative to periods of peak demand. With these so-called coincidence factors in hand, the analyst could use outputs from PAMS to develop reasonably accurate estimates of peak demand savings.

Recommendations and potential solutions for analysts

Analysts embarking on similar projects are encouraged to explore their options and seek out a tool appropriate to the task. But that is only the first step. Finding the data needed as inputs is usually a much more challenging component of any such analysis. This paper identifies several sources of such data.

Unfortunately, much of the data needed for appliance policy analysis is expensive or highly dispersed and difficult to access. There have been some efforts to collect data in the public domain and present them in a standardized and usable form. Three examples are the ODYSSEE Database [4], the Green Cooling Initiative [5], and the en.lighten initiative [6]. The ODYSSEE Database is, among other things, a source of appliance usage data for Europe. The Green Cooling Initiative publishes country data sheets containing sales and stock estimates for refrigeration and space cooling appliances. The en.lighten initiative offers detailed lighting usage and market data for each of more than 100 countries. Much more could be done to gather in one place and catalog the product market and usage data which are foundational for energy efficiency policy analysis.

A large volume of product market data is now available in the public domain in the form of retailer websites and government certification databases. From these sources, the analyst can develop a reasonably accurate picture of the price, efficiency, and other attributes of products on the market today. The SEAD Initiative, recognizing the value of these resources to policymakers, defined a framework and standards for collecting and mining data retrieved from these sources [7]. Analysts around the world are starting to take advantage of this framework to gain access to timely market data and make better decisions.

More information about the three tools and underlying data described in this paper is available from LBNL, CLASP, and the SEAD Initiative.

References

[1] The PAMS tool can be downloaded here: https://ies.lbl.gov/project/policy-analysis-modeling-system

[2] Energy-Efficient Cooling Products in Latin America and the Caribbean: An Opportunity to Cool Down the Planet and Accelerate the Regional Economy," United Nations Environment Programme and CLASP, December 2014.

[3] Lawrence Berkeley National Laboratory, "Potential Global Benefits of Improved Ceiling Fan Energy Efficiency," Super-efficient Equipment and Appliance Deployment Initiative, April 2013.

[4] The ODYSSEE Database is available from http://www.odyssee-mure.eu.

[5] The Green Cooling Initiative's country data are available from http://www.green-cooling-initiative.org.

[6] En.lighten's country assessments are available from www.enlighten-initiative.org.

[7] SEAD Energy Efficiency Data Access Project: Final Report," Super-efficient Equipment and Appliance Deployment Initiative, October 2013. Available from http://www.superefficient.org/dataaccess.