ESTIMATING THE ENERGY EFFIENCY POTENTIAL IN THE INDUSTRY: A HYBRID TOP-DOWN/BOTTOM-UP APPROACH

Ricardo G. A. Lima, Pontifical Catholic University of Rio de Janeiro, +55 61 991813083, ricardo.drenergy@gmail.com
Felipe L. C. da Silva, Federal Rural University of Rio de Janeiro, +55 21 986862233, felipeleite@ufrrj.br
Samuel Santos, Fluminense Federal University, +55 21 980031100, samuelmoreira@id.uff.br
Rodrigo Calili, Pontifical Catholic University of Rio de Janeiro, +55 21 992017170, calili@puc-rio.br
Roberto M. G. Velásquez, Facto Energy, +55 21 982803437, roberto.velasquez@factoenergy.com

Overview

The demands related to energy transition and climate change have been gaining increasing prominence in global discussions, as evidenced by the meetings of the United Nations Climate Conference (COP). In this context, energy efficiency and conservation are presented as strategies to meet international climate demands. The industrial sector, responsible for 32.3% of the country's total energy consumption (EPE, 2022), stands out as one of the main targets for energy efficiency and conservation improvements, as indicated by the Ten-Year Energy Expansion Plan (PDE 2031) (EPE, 2022).

This study adopts an integrated approach by combining top-down and bottom-up forecasting models to assess the potential for energy efficiency in the Brazilian industry, focusing on thermal energy. The chosen methodology enables a comprehensive analysis of energy consumption and scenario variations. While the bottom-up model allows for detailed modelling through a hierarchical structure, as Rehfeldt et al. (2016) exemplified, top-down models provide a broader perspective by exploring causal relationships of energy consumption through econometric models.

Thus, the study aims to identify the potential for thermal energy efficiency in the industrial sector up to 2050, considering diffusion technological scenarios.

Methods

Modelling finds its applicability when employed to estimate energy efficiency potentials for the Brazilian industry, given the hierarchical structure of the industrial sector, which is organized into various segments and presents a wide variety of fuels for different end uses.

The proposed approach enables the estimation of conservation potentials, encompassing macroeconomic and technological diffusion scenarios related to energy efficiency measures. Additionally, the methodology allows changes in technological diffusion scenarios to be considered.

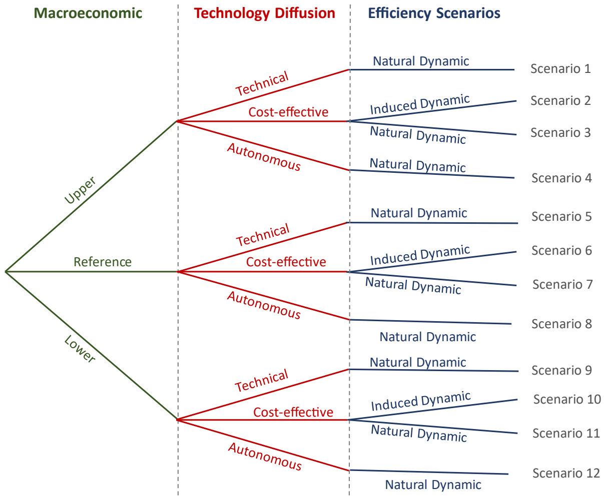
TOP-DOWN APPROACH:

- Top-down approach models use econometric data and provide more aggregated results, offering a comprehensive view of the system. For the application of this model, industrial segments and their correlation with the Industrial Gross Domestic Product (GDP) are considered. After statistical validation, it is possible to derive a linear regression equation that enables production projections based on predefined scenarios. GDP projections are made for reference, as well as upper and lower scenarios in the study horizon.
- Once the production for each industrial segment is calculated based on GDP projections, it becomes possible to estimate the consumption of each energy source in industrial segments for each macroeconomic scenario. This information is essential as initial data for applying the bottom-up approach.

BOTTOM-UP APPROACH:

- In the bottom-up model (SILVA et al., 2018), energy consumption, whether for cooling or heating, occurs in each end-use, comprising industrial processes and equipment. In each industrial process, variables impacting fuel consumption are identified, contributing to the formulation of the bottom-up model.
- Furthermore, in this approach, through technological diffusion curves, it is possible to estimate the potential for energy efficiency in three scenarios according to the methodology developed by the Fraunhofer Institute, TEP Energy, and IREES: autonomous, technical, and economic (JAKOB et al., 2013). Autonomous diffusion assumes that barriers to technology diffusion remain high in the future and represents an extrapolation of past trends. Technical diffusion does not include cost considerations and is based on exogenous inputs such as autonomous diffusion. Economic diffusion is calculated endogenously based on the cost of energy efficiency measures and certain assumptions about companies' investment decision-making.

The combinations of scenarios (macroeconomic, technological diffusion, and efficiency scenarios) are presented in the scenario tree in following figure, resulting in 12 distinct scenarios. It is observed that only economic diffusion unfolds into efficiency scenarios in induced and natural dynamics, whereas technical and autonomous diffusions represent, respectively, the upper and lower limits of economic diffusion. Natural economic diffusion occurs through simple technology efficiency enhancements, inventory accounting, and some improvements routinely adopted by industries. In contrast, induced diffusion is driven by public policies and the implementation of specific energy efficiency programs.



Results

Regarding the efficiency scenarios, the employed methodological approach has proven robust and consistent with historical data, enabling estimates of energy efficiency potential up to the horizon of 2050 that are aligned with the adopted national and international references. The hybrid top-down/bottom-up approach allowed for the estimated energy conservation of 673 ktoe, considering the effective implementation of three cross-cutting policies (training and education program, energy management program and innovation program). Furthermore, in addition to these three policies, one related to the incentive of more efficient thermal equipment was implemented, and the energy conserved in the period could reach 2,989 ktoe.

Conclusions

In summary, the design and application of the Top-down/Bottom-up model to estimate the energy efficiency potential in the Brazilian industry have proven to be a consistent and structured tool, contingent upon the availability of industrial data for more precise application.
The model validation, conducted through comparison with the results from the Ministry of Mines and Energy, demonstrated that the calculated values of the energy efficiency potential in the industry by the Bottom-up/Top-down model are aligned with the order of magnitude of these official results.
Thus, this study provides significant insights into the potential for energy efficiency in the industry and underscores the importance of considering diverse perspectives in crafting effective strategies. In this context, the Bottom-up/Top-down model emerges as a crucial tool to guide public policies and energy efficiency programs, contributing to a sustainable, and economic transition in the Brazilian industrial sector.

References

EMPRESA DE PESQUISA ENERGÉTICA. Atlas de Eficiência Energética 2021/ Ministério de Minas e Energia. Brasília: MME/EPE, 2022.
JAKOB, M.; CATENAZZI, G.; FLEITER, T., Ex-ante estimation of the EU Ecodesign Directive's impact on the long-term electricity demand of the tertiary sector, Eceee 2013 Summer Study, France, 2013
REHFELDT, M.; Fleiter, T.; Toro, F. A bottom-up estimation of heating and cooling demand in the European industry, Enerrgy Efficiency., 1057-1082, 2018.
SILVA, F. L. C.; SOUZA, R. C.; CYRINO OLIVEIRA, F. L.; LOURENCO, P. M.; CALILI, R. F. A bottom-up methodology for long term electricity consumption forecasting of an industrial sector - Application to pulp and paper sector in Brazil. Energy, v. 144, p. 1107-1118, 2018.
WORRELL, E.; PRICE, L. Policy scenarios for energy efficiency improvement in industry. Energy Policy, v 29m p.1223-1252, nov. 2001.

Acknowledgement:

The authors thank the Deutsche Gesellschaft für Internationale Zusammenarbeit for funding the project. We also thank colleagues from the Ministry of Mines and Energy and the Ministry of Industry and Commerce for the discussions.