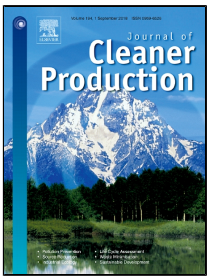
Accepted Manuscript



Modeling the exergy behavior of São Paulo State in Brazil

Rafael Fernandes Mosquim, Silvio de Oliveira Junior, Carlos Eduardo Keutenedjian Mady

PII:	S0959-6526(18)31891-2
DOI:	10.1016/j.jclepro.2018.06.235
Reference:	JCLP 13381
To appear in:	*Journal of Cleaner Production*
Received Date:	07 March 2018
Accepted Date:	21 June 2018

Please cite this article as: Rafael Fernandes Mosquim, Silvio de Oliveira Junior, Carlos Eduardo Keutenedjian Mady, Modeling the exergy behavior of São Paulo State in Brazil, *Journal of Cleaner Production* (2018), doi: 10.1016/j.jclepro.2018.06.235

Modeling the exergy behavior of São Paulo State in Brazil

Rafael Fernandes Mosquim [a], Silvio de Oliveira Junior [b], Carlos Eduardo Keutenedjian Mady [a]

[a] *University of Campinas, Campinas, Brazil, rafael_mosquim@hotmail.com; cekmady@fem.unicamp.br*
[b] *University of São Paulo, São Paulo, Brazil, sol@usp.br*
* Corresponding author. Tel.: +55 19 3521 3275 *E-mail address*: cekmady@fem.unicamp.br (CEK Mady)

Abstract:
Exergy analysis was applied to the state of São Paulo, Brazil, and exergy efficiencies were obtained for its constituent sectors, the Industrial, Rural, Commercial & Public, Residential and Transportation, from most to least efficient. Overall exergy efficiency was found to be 28.3%, a value which lies within the range of similar studies. To indicate the usefulness of the exergy approach, some measures were tested based on exergy efficiency values. LED lamps improve sectorial exergy efficiencies by lowering consumption, but the overall impact is low. Solar water heaters can mitigate the mismatch in quality between supply and demand, in the Residential sector, by harnessing power from an inexhaustible renewable source. For the Transportation sector, with technological constraints regarding similar internal combustion engine efficiencies, improvements were tested on a total carbon dioxide equivalent emission. Gasoline substitution for ethanol was the better option, and fleet electrification produced a wide range of results due to battery production and variability in emission factors from the Utility sector.

Keywords:
Exergy Analysis, Efficiency, Society, São Paulo State, Sustainability.

1. Introduction

Energy use has gathered the attention of the scientific community, governments and general population (Obama, 2017) with regards to potential alterations its use is imposing on the environment, most notably increasing greenhouse gases (GHG) in the atmosphere, and the related increase in the average surface temperature of the Earth observed in recent decades (Pachauri et al., 2015). As such, sustainability concerns should motivate an investigation to the way energy is being used in a society, to help steer it towards more environmental friendly practices.

The First Law of Thermodynamics, when applied in isolation, is not capable of producing the most accurate diagnosis tool, because it disregards the principle that energy transfer has a *quality*. For such information, both the First and Second Laws must be applied together, thus revealing the usefulness of the concept of exergy, defined as the capacity of an energy carrier to perform *useful* work (Kotas, 1985). Two fundamental principles of exergy analysis applied to a society can be gathered from the literature: first, exergy efficiency is always lower than energy efficiency, and there can be a mismatch between the quality of energy supply and demand (Schaeffer and Wirtshafter, 1992).

The exergy losses and destroyed are a quantification of the irreversibility of a system, and how far away it is of an ideal condition. Furthermore, exergy corresponds to the quality of energy in each transformation process and different forms: electricity, chemical, heat (high or low temperatures). Therefore, a future taxation based on the Second Law is a form of minimizing the rate of destroyed exergy by consumers, distributors and producers. Hirs proposed the entropy added tax, as indicated in (Hirs, 1993)