



## **ACTOR-NETWORK THEORY AS A METHOD FOR EVALUATING THE ENERGY SECTORS**

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### **ABSTRACT**

The objective of this article was to evaluate the current utilization of the Actor-Network Theory (ANT) as a research method in the energy sector. High impact scientific articles gathered from the ScienceDirect database were analyzed, taking into account the methodological research particularities (in terms of its nature, objective, issue approach, and technical procedures) and the means of data collection and analysis in the light of the ANT method. Few pieces of research in the energy sector were found utilizing ANT as an analysis method. A pattern for the methodological characterization was identified, in which most of the articles approached ANT as a diagnostic, exploratory, qualitative, and analytical method for case studies. Since most of the papers aimed mainly at the reconstruction of past events, data collection was characterized mainly by searching for documents and, whenever possible, by contacting the players who participated in the reconstructed history. The analysis, though, aimed at identifying the participants and the dynamics of their interactions. The ANT method presents immense potential for research in the energy sector since energy systems evolve throughout complex networks, inseverable from environmental, technological, and social, including those of political and economic nature. Still, as yet, in a continually growing development scenario, ANT's utilization may contribute to understanding how these networks evolve and who plays the most crucial role in it.



**Keywords:** ANT; energy sector; methodological analysis; research method

## 1. INTRODUCTION

Science, Technology, and Society Studies (STS), as presented by Felt et al. (2016) in Handbook of Science and Technology Studies, are defined as a field of multidisciplinary studies that examines the transformative power of science and technology to arrange and rearrange contemporary societies. Woolgar (2009) also reports that STS studies comprise several analytical perspectives, such as social relativism and the Actor-Network Theory (ANT).

The ANT emerges between the end of the 1970s and the beginning of the 1980s, with Michel Callon, Bruno Latour e Steve Woolgar, its precursors, questioning the restricted social reductionism as commonly presented by social theory. Thus, using empirical research, they questioned how science and technology were produced, why some technological and scientific advances are successful and others are not, which allows scientific advances to become truth (Wong, 2016).

The ANT supports society to be, first and foremost, a network formed by associations between actors. On second-hand, this association is a reality model and not a given fact. From this standpoint, human and non-human entities are both as crucial during the association's process (Wong, 2016; Nobre & Pedro, 2010).

This theory allows for identifying important actors (agents, entities, and actants) involved with the process of technology transfer and for the understanding of their participation, interaction, and association with other actors, which form a heterogeneous network. The ANT represents a reflection of those associations involved with this process to understand a social phenomenon in which society represents a type of non-permanent association (Garcia, 2015).

Actant, within ANT's context, can be tangible (like a computer, a file, a protocol, or people), intangible (like software, information, or knowledge), or an interagent (one that interacts with the network being studied, influencing and being influenced within the context of the sociology of associations) (Cavalcante et al., 2017).

The relevance of each human or non-human actant is defined as events happen. Upon taking over a transforming role, the actant is perceived as a "mediator". When acting as a mere emissary, not modifying the situation, it is seen as an "intermediary" (Latour, 2012).

In administration, ANT has been used in organizational studies in Marketing and Supply Chain Management. Networks were approached based on the diversity presented by



inter-organizational relationships, through cooperation among firms, strategic alliances, production chains, and actions and public services programs integration (Andrade, 2004).

One of the most recent sectors in which ANT is being employed is renewable energy. This sector has been sparking worldwide interest, especially since the beginning of the 21<sup>st</sup> Century, due to the global problems concerning energy supply, the rise in oil prices, and worries due to climatic changes (Cambero & Sowlati, 2014).

Despite the available technology, the production potential, and the social-environmental benefits, renewable energy still answers a small share of the world energy matrix, i.e., less than 15% (MME, 2017). To that end, from ANT's standpoint, renewable energies do not hold inherent qualities since they depend on the continuous interaction between their own processes' activities. Through ANT, it will be possible to understand that difficulties faced by renewable energies during the growth process within the energy matrix are coupled with a different network of actants (Hultman & Yaras, 2012).

How ANT is utilized as an analysis method in administration, either in administrative or economic sectors, is as varied as its potential for multidisciplinary applications. Therefore, being ANT is still little utilized in energy research, mapping the significant research pieces that utilize ANT as a method, and understanding how this method is utilized turns out to be our research opportunity. Thereafter, this paper aims to evaluate how ANT is currently utilized as a research method in the energy sector.

## **2. THEORETICAL FRAMEWORK**

### **2.1. Actor-Network Theory (ANT)**

The way authors perceive society and the social is significantly distinct from the traditional sociology approaches, thus configuring a New Sociology. They disregard the concept of society by approaching social as "collectives" of humans and non-humans (objects and quasi-objects) that partner among themselves, forming networks or, more precisely, forming actors-networks (Pinto & Domenico, 2016; Latour, 2012).

The ANT seeks to identify the significant actors (agents, entities, actants, or interactants) involved with the technology transfer and understand their participation, interaction, and association with other actors who form a heterogeneous network. The ANT represents a reflection of those associations involved with this process to understand a social phenomenon in which society represents a type of non-permanent association. In this association, actors will have motivation and interests that will lead to actions, thus justifying the need for constant attention during the process (Garcia, 2015).



In ANT, the network concept must be understood in its broader sense, where each nodal point is constituted by its connections, associations, and articulations with other nodal points under a relational, rather than an individual or unidirectional, perspective. For Latour (2012), the network is ANT's means of flexible, historical, and empirical transportation. This network is formed by heterogeneous elements called actants (human and non-human actors) (Cavalcante et al., 2017).

In the so-called actants, the ANT appears as a differentiated approach vis-à-vis the technological changes theories that regard non-humans (the technology) only as artifacts. When considering both humans and non-humans as agents illustrate one of the most provocative ANT's aspects, the symmetry between one and the other is that no entity is more important than the other, thus being called as actants (Pinto & Domenico, 2016).

The term actant means all that creates action, causing movement and difference. The actant is a mediator, the articulator who will connect and set up the network within himself and externally in association with others. Bruno Latour opts to employ the terms quasi-subjects and quasi-objects to demonstrate that there are no distinctions between the subject and the object, but rather a hybridization in which subjects are formed by their association with objects and vice-versa (Cavalcante et al., 2017).

On the other hand, it is essential to understand what is considered a controversy by the ANT. It is considered a dispute, a discussion or debate between individuals or groups about a subject of common interest. Thus, conflicting groups and anti-groups gather around a controversy, holding opposite positions in a debate. Through controversies analysis, the ANT allows a look into the social aspect while it is formed, in a process called "the mapping of controversies" (Pinto & Domenico, 2016).

Controversy has the objective to debate on a specific knowledge that is not yet totally consecrated. A stable object or a consolidated phenomenon stands for a resolved controversy, creating the so-called black box or a ready, decisive, accurate, and consecrated knowledge (Cavalcante et al., 2017).

## **2.2. The ANT as an analysis tool**

The Actor-Network Theory is an analysis perspective that does not initiate from previously defined assumptions on social, economic, and technical factors. One of its underlying assumptions is that no rigid definition may be applied in all situations (Tureta & Alcadipani, 2009).



For Bruno Latour (2000), the ANT, as a method of network analysis, must consider the following points:

- i) Always objectify a fact while it is active (i.e., when the theme in question is still subject to controversies);
- ii) A fact's condition will be the effect of circulation/interaction of processes throughout the network;
- iii) The stabilization of the evaluated fact shall be the outcome of the controversies resolution;
- iv) All nodes that are being linked during the processes of the network construction/interaction should be symmetrically observed;
- v) Attention must be given to the network extension which is being built in any case of controversy which involves an accusation of irrationality and a search for social or logical explanations that justify said accusation;
- vi) The network that presents unique stability attributes must be tracked.

For the ANT, network tracking lies within the controversies. For Latour (2000), such tracking may be done by focusing on the innovation processes, since at those moments, the network connections are more exposed, and the actors, be them human or not, are more visible.

Allain (2015) states that employing ANT as a method for analysis may be perceived as a mapping practice of controversies, seeking to map complex issues and outline new possible scenarios for the World. Venturini (2010) adds that the method will have as its characteristics a set of tools capable of dealing with the growing hybridization between humans and non-humans and follow disputes that go beyond the disciplinary borders.

From ANT's standpoint, one may also emphasize that the role of research shall not be the resolution of controversies but rather to show the actors, the dynamics of relationships, and the many possibilities of a solution. Thus, the researcher who utilizes this method may present his perceptions and abstractions but should be mindful of neither hide the opinion of others nor immerse in bias (Venturini, 2010).

### **2.3. Areas of knowledge that utilized ANT as an analysis tool**

The ANT has recently aroused interest to an international extent in several areas of knowledge, namely: education, information technology, administration, sociology, history,



planning, geography, environmental studies, information science, public health, and nursing (Cavalcante et al., 2017).

For example, in nursing, Cavalcante et al. (2017) published a paper on ANT as a theoretical/methodological benchmark for research in the health sector, showing the potential for understanding the innovations and their influence on the community based on associations established between the actors.

Another example may be found in the area of Information and Communication Technology (ICT). Fornazin (2015) discusses the difficulties associated with computerization of the practices in the health sector in Brazil, where several areas and daily activities are present, as well as private institutions and government actions.

Another example may be found in education, where Melo (2011) discusses learning as a dynamic, multi-faceted phenomenon, the product of a series of conditions that emerge in a network casualty. Thus, teaching, learning, and building up knowledge shall be a process necessarily linked and tuned with others.

The last example may be mentioned in the Administration sector. Camillis et al. (2016) debate the notion of the actants' partaking, which seeks for the un-dichotomization among human and non-human constituents. To discuss questions regarding partaking is directly related to establishing connections between various constituents, which allows for the assignment of actions to a higher number of actants. Thus, the authors seek to identify and discuss ANT's contributions to organizational studies.

### **3. METHOD**

This paper proposes analyzing ANT while used as a method in scientific studies in the energy sector and is characterized as a qualitative, explanatory, and bibliographic work.

One understands that every research constitutes a rational and systematic procedure, which aims to better understand or solution to identified issues and provide possible answers to any arising questionings. Such a procedure is called a method, which abides by defined operational and intellectual efforts (Roesch, 2006).

A methodological study as the one herein presented allows for the analysis of methods, seeking to understand their characteristics, applications, contributions, and limitations within the scope of their use in scientific research.

Based on the research done in the ScienceDirect scientific articles database, when searching for the terms "ANT", "actor-network theory", and "energy" in papers titles, abstracts, and keywords, 21 articles published between 1999 and 2020 were found. Thus, seven articles



were chosen (Table 1), based on the magazines' impact factor in which those papers were published.

Table 1: Papers Selected for Analysis

Paper	Title	Authors	Year	Journal
1	Exploring the socio-technical dynamics of systems integration and the case of sewage gas for transport in Stockholm, Sweden	Anne-Lorène Vernay; Karel Frits Mulder; Linda Manon Kamp; Hans de Bruijn	2013	Journal of Cleaner Production
2	Blowing against the wind—An exploratory application of actor-network theory to the analysis of local controversies and participation processes in wind energy	Eric Jolivet; Eva Heiskanen	2010	Energy Policy
3	The socio-technological history of hydrogen and fuel cells in Sweden 1978e2005; mapping the innovation trajectory	Martin Hultman; Ali Yaras	2012	International Journal of Hydrogen Energy
4	Assembling Interdisciplinary Energy Research through an Actor-Network Theory (ANT) frame	Catherine Mei Ling Wong	2016	Energy Research & Social Science
5	Multi-level governance, technological intervention, and globalization: the example of biogenetic fuels	Alice B. M. Vadrot; Ronald J. Pohoryles	2010	Innovation – The European Journal of Social Science Research
6	Using Actor-Network Theory to understand planning practice: Exploring relationships between actants in regulating low-carbon commercial development	Yvonne Rydin	2012	Planning Theory
7	Actor-Network Theory, globalized assemblages and the impact of oil on agriculture and industry in Ghana	Pius Siakwah	2017	The Extractive Industries and Society

Source: Prepared by the authors

So, referring to Diehl and Tatim (2004) and Nascimento (2012), all selected articles were methodologically analyzed in the following manner. First, the selected article's methodological characteristics were identified in terms of the Nature of the Research; the Issue Approach; the intended Objective, and the Technical Process were singled out.

Next, the research data collection and analysis process was defined, aiming to understand how ANT was applied. During the final phase, a comparative analysis was prepared to identify standards in the current utilization of ANT in research for the energy sector.

#### 4. Results and Discussion



Tables 2 and 3 show the analysis results for each of the selected studies, obtained by the utilization of three criteria: the research methodological characterization, data collection process, and data analysis process.

Table 2: Analysis of Papers 1 to 4

Analysis Criteria	PAPER1	PAPER2	PAPER3	PAPER4
1) Characterization Research	<p><b>According to the research nature,</b> this article is characterized as diagnostic-research since it has sought to reconstruct an energy project development.  <i>Vernay et al. (2013) used ANT as a structuring theory to analyze sewage gas systems' development for transport in Stockholm.</i></p> <p><b>According to the problem approach,</b> this article is characterized as qualitative.  <i>Vernay et al. (2013) used the ANT to reconstruct the socio-technical micro-processes during the development of an integrated innovation system through textual data. That is, identifying the actors and their actions that led to network construction.</i></p> <p><b>According to the objective approach,</b> this article is characterized as exploratory and descriptive.</p> <ul style="list-style-type: none"> <li>• Exploratory  <i>The history of the network construction was explored through reports and</i></li> </ul>	<p><b>According to the research nature,</b> this article is characterized as diagnostic-research since it has sought to reconstruct an energy project development.  <i>Jolivet and Heiskanen (2010) analyzed the implementation of a wind energy generation system and the controversies that came by during the process in the region of Carmaux in southern France.</i></p> <p><b>According to the problem approach,</b> this article is characterized as qualitative.  <i>Jolivet and Heiskanen (2010) followed an analytical approach driven towards exploring the interaction between Technologies available for the execution of the Wind energy project, the particular local characteristics, the stakeholders' participation process, and the social dynamics that arose during the whole process.</i></p> <p><b>According to the objective,</b> this article is characterized as</p>	<p><b>According to the research nature,</b> this article is characterized as diagnostic-research since it has sought to reconstruct the technological development of fuel cells in Sweden.  <i>The research focused on mapping the socio-technical changes between 1978 and 2005, a period during which fuel cells were included in different visions of energy systems, initially playing the role of energy transformers and later being described as a source of energy (HULTMAN; YARA, 2012).</i></p> <p><b>According to the problem approach,</b> this article is characterized as quantitative and qualitative.</p> <ul style="list-style-type: none"> <li>• Quantitative  <i>Hultman and Yara (2012) built a database containing the most critical and recurring words, as well as significant events listed in chronological order. The identification of events and recurring words was an inductive exercise, from which the analysis was done. A quantitative analysis was previously done</i></li> </ul>	<p><b>According to the research nature,</b> this article is characterized as results evaluation since it aimed to evaluate the potential of applying ANT as a method for interdisciplinary energy research.  <i>Energy systems are of social and technical nature, which is shaped by society, but shapes society as well, inasmuch it evolves. Thus, interdisciplinary energy research may profit from social science, through ANT, since human and non-human actors form the energy systems. (WONG, 2015).</i></p> <p><b>According to the problem approach,</b> this article may be characterized as qualitative.  <i>Wong (2015) made a qualitative evaluation of ANT's technological potential in energy systems multidisciplinary researches; debating that ANT may improve the understanding</i></p>



	<p>statements furnished by the interviewed subjects.</p> <ul style="list-style-type: none"> <li>• Descriptive The pros and cons of actors and their actions during the sewage gas system for transport development in Stockholm city were described.</li> </ul> <p><b>According to the technical procedure,</b> this research is characterized as a case study, supported by documental research.</p>	<p>exploratory and descriptive.</p> <ul style="list-style-type: none"> <li>• Exploratory Throughout the project's history, one attempted to identify all actors that either contributed or hampered the implementation of wind energy in the area. Accordingly, controversies among the actors were also mapped, such as the technology, the project location, and city residents' participation that were "benefited" or "impacted".</li> <li>• Descriptive The project details and the context within it had been proposed were described (the Cap Eole project was part of a broader project involving the industrial revitalization of an old coal mining area, which went out of business in 1997. The project was called "Cap Discovery" and intended to attract tourists and create new jobs.)</li> </ul> <p><b>According to the technical procedure,</b> this research is characterized as a case study, mainly supported by documental research.</p> <p>The exploration and description of the Cap Eole project implementation case searched, "in loco," the data that allowed for identifying actors and controversies.</p>	<p>using that material, which shows how fuel cells change over a while.</p> <ul style="list-style-type: none"> <li>• Qualitative The research focused mainly on the description of changes in the fuel cells' functions over time. These changes go beyond their materiality. Therefore, the qualitative approach was more important, as it concentrated on the entities' description and its relations, which brought meaning to the new technology. (HULTMAN; YARA, 2012).</li> </ul> <p><b>According to the objective,</b> this article is characterized as exploratory and descriptive.</p> <ul style="list-style-type: none"> <li>• Exploratory Hultman and Yara (2012) attempted to reconstruct the fuel cell history from 1978 through 2005, trying to identify all technology development phases, either from the material or from the social standpoints. In this sense, the ANT method made it possible to identify and follow the actors' steps that played an essential role in the fuel cell history's history.</li> <li>• Descriptive Hultman and Yara (2012) reported the history of the fuel cell, describing the role and the description presented by the actors over creating the network. The</li> </ul>	<p>of risks and problems involved with energy, technology, and social issues.</p> <p><b>According to the objective,</b> this article is characterized as exploratory. Wong (2015) states that ANT concepts like semiotic-material, heterogeneity, associations, enrolment, enactment, translation, and mobilization may help to structure an energy research issue in such a way that it could reconcile researchers, concepts, features, and data previously divergent and distinct.</p> <p><b>According to the technical procedure,</b> this article is characterized as a bibliographic one. Using the ANT method, Wong (2015) studies sociology as a science that could contribute to the research in the energy sector. Thus, she studies the available bibliography on ANT.</p>
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			<p><i>technology and its features were also described. Finally, it was possible to describe how fuel cell history shows that technological change is intertwined with social changes.</i></p> <p><b>According to the technical procedure,</b> this paper is characterized as documental and bibliographic research.</p> <p><i>The research focused on the gathering and analyzing several types of public documents (articles, reports, the WELGAS Project data, among others) at the time that encompassed the studied period.</i></p>	
<p><b>2) Data Collection</b></p>	<p>Data were collected in a structured manner in the City of Stockholm.</p> <p>For this kind of data collection, the researcher defines the process based on what is being searched. In this case, social and technological agents that have participated in the network construction.</p> <p><i>About a dozen reports prepared between 2000 and 2011 were collected. Technical reports, annual reports covering Stockholm, press releases, and specialists' presentations and city representatives were among those documents.</i></p>	<p>Data were collected through documental research, considering the article's methodological characteristics and searching for all kinds of documents related to the Cap Eole and the Cap Discovery Projects.</p> <p><i>Since the research aimed at analyzing the Project implementation, data collection was done at the same location where the dynamic interactions between the Project participating actors happened. Thus, one gathered technical data about the Eolic energy Project, geographical, historical, and social characteristics pertinent to the</i></p>	<p>Data collection was done, taking into account the following questions: Who are the actors? What ideas and visions did they have about the fuel cell? How is the global energy system depicted? How are fuel cells brought to function considering the dominant discourse at the period under analysis?</p> <p><i>In this manner, Hultman and Yara (2012) gathered a wide variety of documental data between 1978 and 2005. All articles related to fuel cells and hydrogen that were published in Sweden during that period were gathered. Also,</i></p>	<p>Data collection was done, taking into account the following questions:</p> <p>How can we consider the viability of interdisciplinary research? Which social sciences concepts, specifically those within ANT, are currently available or must be made available or adapted to engage in technical research about energy systems?</p> <p>Thereby, the author collected articles and bibliographic material on ANT. She also revealed that the utilization</p>



	<p>Also, semi-structured interviews with the City of Stockholm Representative, an SL Project Manager, and a Stockholm Water Project Manager took place.</p>	<p>region where the Project was implemented as well as the participation by each stakeholder.</p>	<p>Companies and Government reports were collected, including some published by the United States and by the European Union. Also, documents related to the WELGAS Project, which took place during the '80s, were gathered.</p>	<p>of ANT in the energy area is recent but has been raising the interest of researchers due to the significant impact and risks to society, the economy, and the environment, exerted by energy projects.</p>
<p><b>3) Data Analysis</b></p>	<p>Based on the Actor-Network Theory (ANT), contents analysis was done to critically and reflexively describe the actors and the dynamics in their associations. Thus, it was possible to reconstruct the integrated innovation system that expressed the City of Stockholm transport's sewage gas system.</p> <p>This reconstruction also allowed for the preparation of tables and flowcharts that enhanced the network construction's understanding.</p> <p>Through ANT, the authors were able to construct a heterogeneous network of actors who had interests aligned with the sewage system Project.</p> <p>The authors realized that to attain the objective, a network of human and non-human actors with aligned interests is formed; and that the network itself, during its creation, is responsible for the access of new actors.</p>	<p>In addition to the Actor-Network Theory (ANT), the authors analyzed the collected data based on the "framing" and "overflow" notions (CALLON, 1998) in order to understand better the different points of view of the stakeholders concerning the wind energy project; either those that adhered to it as those that resisted to its deployment.</p> <p><i>The micro-decisions that intertwined the material aspects of technology, the site where it was implemented, the participation process, and the social (associations) were analyzed. The authors' analysis suggests a new approach to examining the Wind Power Projects in terms of the globally circulating technologies, the site's unique characteristics, the participation process, and the social dynamics that emerge when these are combined.</i></p> <p>In addition to the critical and reflective</p>	<p>First, the authors built a database in an attempt to quantify and identify patterns, as well as to be able to arrange the significant events chronologically.</p> <p>Next, the researchers concentrated on the qualitative analysis of the data collected. The network construction and changes caused by the actors' participation and interaction were descriptively and critically analyzed. To that effect, the actors' speeches found in the documental material were analyzed.</p> <p>Hultman and Yara (2012) analyzed how the fuel cells' role and function changed during the period studied, being dependent on the different speeches and changes in the network of participant actors. That analysis was able to demonstrate how technological changes intertwine with social changes. Thus, one can observe that the authors attempted to use ANT to recreate</p>	<p>The author follows through with reflexive questions about the role of the social in energy project issues to analyze the collected bibliographic material.</p> <p>Wong (2015) critically and reflexively analyzes ANT's concepts like material-semiotic, heterogeneity, associations, enrolment, enactment, translation, and mobilization, stating that these concepts may help better structure the research issues in energy projects.</p>



		<p>analysis, the authors counted on the formative evaluation analysis by suggesting how a Project Manager should behave to achieve success in the deployment of an energy Project.</p> <p><i>A successful Project Manager shall be an actor who continually reformulates and adapts his project, channeling and stabilizing the creation and implementation process of an Energy Project as the Wind Energy Park. This stance will gradually allow for the adaptation of the project to its environment and its concretization. Usually, Project Managers show a lack of knowledge about the relevant socio-technical networks' extension and potential.</i></p>	<p><i>history in a reflexive form, having as study object an energy generation technology.</i></p>
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Table 3: Analysis of Papers 5 to 7

Analysis Criteria	PAPER5	PAPER6	PAPER7
1) Characterization Research	<p><b>According to the research nature</b>, this article is characterized as diagnostic-research since it attempts to understand through a case study how the network that supports the production of ethanol fuel stabilizes, despite the increasing number of critics and the criticism about the negative impacts caused by the biofuel production processes. <i>Vadrot and Pohoryles (2010) examine the increasing cooperation for</i></p>	<p><b>According to the research nature</b>, this article is characterized as diagnostic-research since it attempts to explore ANT to understand the planning practice in a project that is aimed at reducing the carbon emission performance. <i>Rydin (2012) focused on testing the Actor-Network Theory's potential to understand a world in which technological systems and climatic changes are constant concerns.</i></p>	<p><b>According to the research nature</b>, this article is characterized as diagnostic-research since it attempts to analyze, through a case study, how ANT may be used to understand the way that globalized actors interact with national economics, thus influencing development. <i>Siakwah (2017) used the Actor-Network Theory to analyze the oil impact on three areas of Ghana's economy: agriculture, industry, and employment.</i></p>



	<p><i>development in the field of biofuels, particularly bioethanol, given the increasing knowledge on positive and negative impacts caused by the production and use of biofuels.</i></p> <p><b>According to the problem approach,</b> this article is characterized as qualitative.</p> <p><i>Vadrot and Pohoryles (2010) attempted to identify and describe through ANT the actors and associations involved with ethanol fuel production in Senegal. In this OPEC member country, biofuels became relevant within the inter-relation with the European Union incentive policies.</i></p> <p><b>According to the objective,</b> this article is characterized as exploratory and descriptive.</p> <ul style="list-style-type: none"> <li>• Descriptive</li> </ul> <p><i>The article is based on a three-year research project for the Austrian Research Society FFG. It carefully analyzed the biofuel production in the Sahel zone in Senegal, against the background of European policies and legislation. (VADROT; POHORYLES, 2010).</i></p> <ul style="list-style-type: none"> <li>• Exploratory</li> </ul> <p><i>The article attempts to identify actors and the dynamics of associations that contribute to stabilizing the ethanol production network,</i></p>	<p><b>According to the problem approach,</b> this article is characterized as qualitative.</p> <p><i>Ryadin (2012) focused on analyzing how network planning during regulation, as seen from ANT's standpoint, engages with energy consumption and the carbon emissions associated with development.</i></p> <p><b>According to the objective,</b> this article is characterized as exploratory and descriptive.</p> <ul style="list-style-type: none"> <li>• Exploratory</li> </ul> <p><i>One tried to explore ANT's potential for understanding the planning of the urban development of carbon emissions by using a case study about a Commercial Office in Central London through its course through the process for regulation and permission for its execution.</i></p> <ul style="list-style-type: none"> <li>• Descriptive</li> </ul> <p><i>Project details were described within the context into which it had been proposed (one starts by outlining ANT's essential elements and, next, using the case study to apply the method and, thus, identify the implications on the planning practice).</i></p> <p><b>According to the technical procedure,</b> this article is characterized as a case study, mainly supported by documental research.</p> <p><i>One utilized a study based on the analysis of documents on commercial offices' development and the discussion on its carbon performance within the</i></p>	<p><b>According to the problem approach,</b> this article is characterized as qualitative.</p> <p><i>Based on network geographies, one argues that the impact of oil on Ghana's agriculture, industry, and employment creation is contingent on and shaped by a 'globalized assemblage': interactions between the state, institutions, local politics, and transnational actors and structures.</i></p> <p><b>According to the objective,</b> this article is characterized as exploratory and descriptive.</p> <ul style="list-style-type: none"> <li>• Exploratory</li> </ul> <p><i>Through ANT, one attempted to understand the oil impact on three areas of Ghana's economy (agriculture, industry, and employment). It was revealed that oil has only diversified its dependence on natural resources without structurally changing the national economy.</i></p> <ul style="list-style-type: none"> <li>• Descriptive.</li> </ul> <p><i>Details of the oil exploration Project were described, including the context for which it had been proposed.</i></p> <p><b>According to the technical procedure,</b> this article is characterized as a case study, mainly supported by documental research.</p> <p><i>Data for this study was collected from books, articles, documents on politics (between 2010 and 2015), firms' reports, and reports from Civil Society Organizations. Also, statistical data was used to analyze the agricultural and industrial growth tendencies and prepare interviews to identify the perceptions of the impacts of oil on the corresponding economic sectors (SIKWAH, 2017).</i></p>
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	<p>despite the increase in criticism (VADROT; POHORYLES, 2010).</p> <p><b>According to the technical procedure,</b> this article is characterized as a case study.</p> <p>Over three years, the production of biofuels in the Sahel zone in Senegal and the European laws directed at biofuels were analyzed. (VADROT; POHORYLES, 2010).</p>	<p>regulatory planning process. Also, a site visit and discussions with British Land's sustainability officer, with two architects from Arup Associates and the planning consultant, took place.</p>	
<p><b>2) Data Collection</b></p>	<p>Data collection was done via a three-year research project, which aimed at the close analysis of biofuel production in the Sahel zone of Senegal.</p> <p>Energy firms' representatives were interviewed. Documental data was collected, as was data obtained through direct observation.</p>	<p>Data collection was based on documents, a site visit, and discussions with British Land's sustainability officer, two architects from Arup Associates, and a Planning Consultant, all undertaken during 2010-2011.</p> <p>The City of London's government plans, as well as planning application files and the Sustainability Statement (including the Energy Statement) submitted by the project developer, were collected.</p> <p>For this type of data collection, the researcher plans to be aware of the expected type of data. In this case, one sought networks associated with the Office from ANT's standpoint, constructed during the planning phase and Project regulation, focusing on energy consumption and the associated carbon emissions.</p>	<p>Data for this study was collected mainly from books, articles, documents on politics, firms' reports, and reports from Civil Society Organizations.</p> <p>For example, the annual reports from Tullow, issued between 2010 and 2013, identify how the oil industry contributed to employment and the Country's industry growth. In turn, the statistical data helped analyze tendencies in economic, industrial, and agricultural activities.</p> <p>The only primary data collected were through interviews undertaken between May 2014 and January 2015, with officers from government agencies, oil companies operating in the Country, and Civil Society Organizations.</p> <p>Purposeful sampling was used to select the interviewed subjects, as this allowed the researcher to choose targets who were better-informed about oil-related activities. Twenty-five interviews took place, and the discussed matters included employment, work conditions, industrial growth,</p>



			<p>technology transfer, and agriculture growth.</p>
<p><b>3) Data Analysis</b></p>	<p>The analysis was done based on ANT, evaluating processes, technologies, actors, associations, the stabilization, and destabilization of the network that seeks to develop ethanol fuel production.</p> <p><i>Thus, one may identify the importance of cooperation between countries and the intervention of specific actors; the importance of the adhesion of new actors, like the second-generation biofuel, although not yet economically viable, and the useful technological perspectives which contribute to reinforcing the confidence on the current production and use of biofuels (Vadrot; Pohoryles, 2010).</i></p> <p><i>Despite biofuel's defense, a critical analysis was done on the limitations faced by offer and demand, even in cultures highly available and efficient in ethanol production, like sugarcane and jatropha. (VADROT; POHORYLES, 2010).</i></p>	<p>The UCINET software and the Actor-Network Theory were used for understanding the planning practice. Relations among actors in the regulation of low-carbon commercial development were explored.</p> <p><i>It was not the author's intention to analyze social network (which would be in disagreement with the ANT structure), but rather map the relations in an illustrative and provocative manner, complementing ANT's analytical method.</i></p> <p>The evaluated case deals with a Project of a building employing renewable energy and low energy consumption technology. The analysis considered the relations between the major social actors involved with planning the building (the Architect, the Developer, and the Project Development Controller).</p> <p>Finally, one attempted to understand ANT's contribution to the planning theory. It was concluded that planning practice means working with actors (social and material) in various ways, using mediators to bring actants into relationships, so that traceable associations and resultant action can be generated.</p>	<p>Data were analyzed using ANT, in an attempt to identify the actors and construct a network of interactions between oil exploration and the economic activities related to agriculture and industry, besides employment generation.</p> <p>The analyzes came up with a diversity of actors, including external actors, who act like a Globalised Assemblage, which, by the way, influences the Country's economic policy. This policy plays a determinant role in job generation and the sector economic activities, and consequently, in the impacts of the Country's oil activities.</p> <p>Thus, the research argues that oil may be a problem for the development in peripheral countries due to interactions between the actors and the global structures that include national and local policies. It was precisely by using ANT that one could identify the so-called Globalised Assemblage and its interaction within the local scenario.</p> <p><i>Siakwah (2017) examines how the external political-economic environments interact with the national economic policies as part of an assemblage that conditions and shapes natural resources' specific impacts.</i></p> <p><i>Siakwah (2017) also argues that due to its colonial legacy, Ghana's economy is characterized by its dependency on the exportation of raw materials and importing manufactured products. Moreover, nowadays, Ghana presents</i></p>



			<i>unfavorable relationships and structural dependency.</i>
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Upon comparing the methodological characterization of seven evaluated papers, one can observe that the majority of the papers were of the diagnostic-research type according to the research-nature. The use of ANT allowed, through the reconstruction of past events, the actors' identification that influenced the respective studied network history, and understanding the role of each of the actors.

In paper four by Wong (2015), it should be noted, which, according to its research-nature, was characterized as a results-evaluation type since it evaluated ANT's potential as a method for interdisciplinary energy research. The idea is strengthened that ANT is used as a diagnostic method for risks linked to the energy systems, involving the technology, the environment, and society.

According to the Problem Approach, one identified the preponderance of the qualitative characteristic. The ANT is a social science tool and makes use of documentary and discursive data.

According to their Objective, the evaluated papers presented exploratory and descriptive characteristics. That is, ANT enabled the research to identify the actors and better understand the controversies that were part of the network's dynamics of associations.

From the Technical Procedure perspective, one takes that ANT is a method utilized to evaluate study cases. The systematic bibliographic and documental research were used in addition to participatory research, when actors of the evaluated network were interviewed, as noted in papers 5 and 7.

In the second phase of the methodological analysis, the evaluated papers' data collection process responded to the characteristics identified in the first phase of this analysis. One referred to bibliography, documents, and reports, including those obtained directly from the actors involved with the case study, as well as some statements made by them.

Finally, upon comparing the data analysis process, the ANT was not applied in a strictly standardized manner. The Latour (2000) assumptions, such as focusing on objects that still present some controversy and the detection of stabilization and instability conditions throughout the network, were not observed.

However, Tureta and Alcadipani (2009) argue that there are no strict definitions for ANT's analytical application in every situation. This analytical liberty was identified in the



papers studied. Sometimes more emphasis is given to actors and their discourse, while in other cases, priority is given to the analysis of associations and controversies. Even formative analysis is made, resulting in suggestions for strengthening the studied network, as in paper 2, by Jolivet and Heiskanen (2010).

One may also say that the analyzed papers, in their majority focused on the reconstruction of histories or past events, probably faced data availability as their major limitation. This constraint must be overcome during the utilization of the ANT method, which, as stated by Allain (2005), constitutes a cartographic practice of controversies or the mapping of all problems, which during the data analysis phase, will enable the delineation of new scenarios for the associations among the identified actors.

Finally, it is possible to highlight that ANT, as an analytic method for study objects related to the energy sector, allows for identifying human and non-human actors that play an essential role in the development of energy projects. As Venturini (2010) mentioned, they do not seek the solution of controversies, but rather for the understanding of the dynamics of relationships that made the expansion and stabilization of the evaluated network possible.

## **5. FINAL CONSIDERATIONS**

ANT is a social sciences method with a broad potential for utilization in several areas of knowledge. For research in the energy sector, ANT may be seen as a qualitative method that contributes to a systemic understanding of projects developed for the area; meaning that it helps to understand energy's role as a function of associations with other actors, with the technology, with the environment, and with society.

Even though most evaluated articles utilized ANT for network analysis of concluded cases, one understands that this method can be applied to networks under construction. In the energy sector, ANT could also analyze energy systems under construction, especially in a global context involving efforts aimed at sustainable development. The tool would identify the major actors and those associations that would favor the expansion and stabilization of networks.

To that end, considering the current context of a quest for sustainable development, bioenergy sustainable energies systems could benefit from the ANT method's analytical potential.

Regarding papers evaluated limitations, how ANT was utilized for the collected data analysis, after the actor's identification and the network's extension, did not clearly show how



the interactions are ruled and how those actors interfere, in cases of adhesion or abandon, with the development and stability of the network. For this reason, one believes the contributions of other instruments to be significant, as is the case of the UCINET networks analysis software, mentioned by Rydin (2012).

As a method in the energy sector studies, the ANT is still little used but holds a broad potential, mainly because energy systems are inseparable from environmental, technological, and social factors, including politics and economy. Because of this, one believes that the increase in energy research utilizing ANT as an analysis method will contribute to the development of its analytical potential, considering that broad, complex, and dynamic networks are part of that sector even because new networks have continuously been introduced to the World.

## 6. ACKNOWLEDGMENTS

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## REFERENCES

- Allain, L. R. (2015). **Mapping the professional identity of undergraduates in biological sciences: an actor-network study based on the institutional teaching initiation scholarship program**. Doctoral thesis, Faculdade de Educação da Universidade Federal de Minas Gerais, Belo Horizonte. Available: <http://hdl.handle.net/1843/BUBD-A3NEYP>.
- Andrade, J. A. (2004). A translation to understand the relational and the structural in interorganizational networks. **Cadernos EBAPE.BR. FGV**, 2(2), 01-14.
- Camero, C., & Sowlati, T. (2014). Assessment and optimization of forest biomass supply chains from economic, social and environmental perspectives – a review of literature. **Renewable Sustainable Energy Review**, 36, 62–73.
- Camillis, P. K., Bussular, C. Z., & Antonello, C. S. (2016). The agency in the perspective of the actor network theory: reflections and contributions to management research. **Organizações & Sociedade**, 23(76), 73-91.
- Cavalcante, R. B., Esteves, C. J. S., Pires, M. C. A., Vasconcelos, D. D., Freitas, M. M., & Macedo, A. S. (2017). The actor-network theory as a theoretical-methodological framework in health and nursing research. **Texto & Contexto – Enfermagem**, 26(4).
- Diehl, A. A., & Tatim, D. C. (2004). **Pesquisa em ciências sociais aplicadas: métodos e técnicas**. São Paulo: Prentice Hall.
- Felt, U., Fouche, R., Miller, A. C., & Smith-Doerr, L (2016). **The Handbook of Science and Technology Studies**. 4th edition. MIT Press.
- Fornazin, M. (2015). **Deploying Health Informatics in Brazil: An Analysis inspired by the Actor-Network Theory**. Doctoral Thesis – Public Administration, Escola Brasileira de Administração Pública e de Empresas da Fundação Getulio Vargas, Rio de Janeiro. Available: <https://bibliotecadigital.fgv.br/dspace/handle/10438/13744>



Garcia, M. O. (2015). **The technology transfer process in universities Minas Gerais State from the perspective of Actor-Network Theory**. Msc Thesis, Universidade Federal de Viçosa, MG. Available: <http://www.locus.ufv.br/handle/123456789/6352>

Hultman, M., & Yaras, A. (2012). The socio-technological history of hydrogen and fuel cells in Sweden 1978-2005., mapping the innovation trajectory. **International Journal of Hydrogen Energy**, 27, 12043-12053.

Jolivet, E., & Heiskanen, E. (2010). Blowing against the wind – An exploratory application of actor-network theory to the analysis of local controversies and participation processes in wind energy. **Energy Policy**, 38, 6746–6754.

Latour, B. (2000). **Ciência em ação: como seguir cientistas e engenheiros sociedade afora**. São Paulo: Editora UNESP.

Latour, B. (2012). **Reagregando o social: uma introdução à teoria do ator-rede**. São Paulo: Editora EDUSC.

Melo, M. F. A. Q. (2011). Discussing learning under actor-network theory perspective. **Educar em Revista**. Curitiba, PR: Editora UFPR, 9(39), 177-190.

MME - Ministério de Minas e Energia – Secretaria de planejamento e desenvolvimento energético (2017). **Resenha energética brasileira**. Available: <http://www.mme.gov.br/documents/10584/3580498/02+-+Resenha+Energ%C3%A9tica+Brasileira+2017+-+ano+ref.+2016+%28PDF%29/13d8d958-de50-4691-96e3-3ccf53f8e1e4?version=1.0>. Accessed: 15th Dec 2019.

Nascimento, L.P. (2012). **Elaboração de Projetos de Pesquisa: monografia, dissertação, tese estudo de caso, com base em metodologia científica**. São Paulo: Cengage Learning.

Nobre, J. C. A., & Pedro, R. M. L. R. (2010). Reflections about methodological possibilities of the Actor-network Theory. **Cadernos UniFOA**, Volta Redonda, 14.

Pinto, C. C., & Domenico, S. M. R. (2016). Change and Actor-Network Theory: Humans and Non-Humans in Controversies for Implementing a Shared Services Center, **Cadernos EBAPE.BR**, 14(1), 83-115.

Rydin, Y. (2012). Using Actor-Network Theory to understand planning practice: Exploring relationships between actants in regulating low-carbon commercial development. **Planning Theory**, 12, 23–45.

Roesch, S. M. A. (2006). **Projetos de Estágio e de Pesquisa em Administração**. 3. ed. São Paulo: Atlas.

Siakwah, P. (2017). Actor-Network Theory, globalized assemblages and the impact of oil on agriculture and industry in Ghana. **The Extractive Industries and Society**, 4, 462-472.

Tureta, C., & Alcadipani, R. (2009). The object in organizational analysis: actor-network theory as an analytic method about the participation of non-humans in organizing. **Cadernos EBAPE.BR**, 7(1), 50-70.

Vadrot, A. B. M., & Pohoryles, R. J. (2010). Multi-level governance, technological intervention, and globalization: the example of biogenetic fuels. **Innovation – The European Journal of Social Science Research**, 23(4), 361–387.

Venturini, T. (2010). Diving in magma: how to explore controversies with actor-network theory. **Public Understanding of Science**, 19(3), 258-273.



Vernay, A.-L., Mulder, K. F., Kamp, L. M., & De Bruijn, H. (2013). Exploring the socio-technical dynamics of systems integration – the case of sewage gas for transport in Stockholm, Sweden. **Journal of Cleaner Production**, 44, 190–199.

Wong, C. M. L. (2016). Assembling Interdisciplinary Energy Research through an Actor-Network Theory (ANT). frame. **Energy Research & Social Science**, 12, 106-110.

Woolgar, S., Coopmans, C., & Neyland, D. (2009). Does STS Mean Business? **Organization**, 16, 5–30.

