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Electricity Supply Chain Management – A Literature Review

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EXECUTIVE SUMMARY

Supply Chain Management is not a Discipline, but it is becoming one. Supply Chain as Network is a modern definition of a field with more than 37 years of reliable scientific publications. And it has great complexity even greater when world is experiencing the Forth Industrial Revolution.

Electricity Supply Chains were delimitated as those compounded by first tier of oil, gas or coal (energy production majority), the generators, the transmitters, the distributor retailer until end-consumer. It has a great complex network constituted by external organisms responsible for coordinating and giving the strategy to the whole system.

Lean and Agile is something less usual in Electricity Supply Chain. This researcher was unable of finding scientific articles reporting directly about that combination. However, Electricity Supply Chain is considered a functional product with long life cycle. The coal, the gas and the oil are also functional products and they are controlled with efficient perspective. It is concluded that Electricity supply chain is more designed for a lean environment to an agile positioning.

The industry 4.0 is transformed the whole Electricity Supply Chain, especially the electric utility. It is using Big Data for generating extra businesses, and for improving operational conditions. The smart meter and the smart grid, using sensors and the Big Data, coordinate a more precise cycle of production and consumption, transforming Electricity Supply Chain into a responsiveness one with real date and virtual networks.

INTRODUCTION

Supply Chain Management has a bunch of different definitions. It is not a closed meaning especial for the day by day of each organization. Some companies defend that supply chain is only the channel for buying surplus, others see it as integrated planning, and for us it is characterized as "***A modern supply chain is a dynamic network of great complexity. Thus, organizations should strive for developing supply chain strategies, configuring supply chains to maximize performance and coping with technological changes***" (Papanagnou, 2017).

Following that definition and considering supply chain as a network, it is represented for relationships between organizations. Some scholars affirm that supply chain is the new model of competition, a company is not anymore fighting for market alone, it has its own supply chain partners and strategies, configuring those for maximize performance and take some core competencies against other supply chains configurations.

The aim of this article is to characterize supply chain management as a network, giving examples of how it works into the electricity sector, field where the researcher works for. It is divided into four sessions. First, it gives a further definition of supply chain as a dynamic network. Then, it shows the design and implementation of supply chain management into electricity utilities, looking for best practices. So, it demonstrates how organizations of electricity utilities configure those supply chains through collaboration, lean principles and agility. Finally, it demonstrates how advanced technology are utilized by companies within the sector to maintain their competitive advantages.

SUPPLY CHAIN DEFINITION

There is no consensus about supply chain management definition (SCM). Although it is a relative old term - it was used for the first time in 1982 - it presents different perspectives. For some authors it is a philosophy, a process, a Functional Area in an organization, but for others it is a Discipline. (Ellram and Cooper, 2014). The same authors, however, appointed that SCM is in the correct path, there are some evidences that it is going to become a Discipline.

And a Discipline has some clear definitions and a "set of researchers with a common focus" (Harland et al, 2006 cited in Gold, 2014). Gold (2014) affirmed that supply chain became a "hot topic" in the 2000s. For a Lakatosian perspective, the same author produced some evidences that also show supply chain can be transformed into a Discipline. There are two main point of views "the hard core" and the "protective belt" which, for the author, are complementarian and not excluding from each other, when applied Lakatosian perspective in a Supply Chain context. Once SCM is not a well-defined term, the supply chain as network is not a consent either. Hugos (2011) cited in Govidan et al (2017) defended that SCM is different of logistics management. Whilst logistics management is concerned about "inventory management, distribution, and procurement" of a single organization, SCM would include other activities such as "Marketing, Customer Services and Finance". What it can be concluded, because of those subjects are inter-organizational - that supply chain needs other organizations and it is concerned about the relationship between those entities.

If there is a relationship, so it is correct to affirm that there is a network therefore. However, the network can be coordinate or not. If it is not coordinate it is considered a Traditional Supply Chain, without some inventory collaboration and without planning collaboration between those organizations, (Holweg et al 2005). Anyway, it still has "a complex and dynamic network of great complexity" which can indeed condemn that business format to be expelled from the market. An important supply chain, thus, implement conditions to develop strategies and cope with new technologies.

It is important to be said that there are two important councils studying SCM. One is the CSCMP (Council of Supply Chain Management Professionals) and the CIPS (Chartered Institute of Procurement & Supply). The CSCMP defines supply chain management as:

> *"Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies". (CSCMP, 2018)*

With this definition it can be understood how supply chain management and networks are designed. It starts involving planning and management, from procurement to logistics, through coordination to collaboration within channel partners. Once this is taken as right, then it is simple to get the idea of dynamic network (from channel of partners) and the necessity to implement strategies in that whole channel and to cope with new technologies for integrate supply and demand management.

Another good definition is brought by LeMay et al (2016). It corroborates with Council of Supply Chain Management Professionals (2018) and Papanagnou (2017).

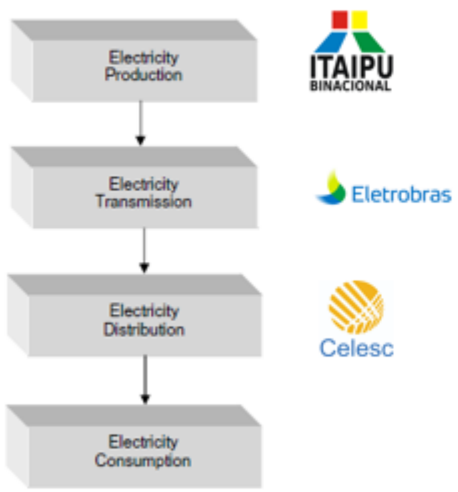
> *"Supply chain management is the design and coordination of a network through which organizations and individuals get, use, deliver, and dispose of material goods; acquire and distribute services; and make their offerings available to markets, customers, and clients". (LeMay et al (2016).*

ELECTRICITY SUPPLY CHAIN

It will be described as electricity supply chain only the network of traditional central electricity production from water, wind, coal, gas, crude oil, sun light and others. It is different what proposes Halldórsson and Svanberg (2013) which had described the heat and the traditional vehicle fuel as part of electricity supply chain.

A supply chain is constituted by tiers, Tortorella et al (2017), for instance, cited some differences between tiers involvements. In electricity supply chains, there are suppliers of generators, generators (producers), the transmitter (wholesaler), the distributor (retailer or utility), until arrive to end-consumers (Lukić et al, 2015). In some countries as Uruguay, one company is the producer, the transmitter, and the distributor, in that example, UTE. UTE`s model is a vertically integrated supply chain (Gugler et al, 2017), Forgionne and Guo (2009) called it an internal supply chain. Other countries such as Brazil, the producer (generator) is the second tier (example, Itaipu), the transmitter the first tier (example, Eletrobras) on a retailer focused supply chain (example, Celesc).

Figure 1: Brazilian Electricity Supply Chain. Source: Forgionne and Guo (2009), adapted



Most part of countries opened their market during the 80's and 90's, thus, international companies become common producers, distributors and transmitter in other countries. Frei et al (2018) pointed out some of the biggest players in the electric sector. EDP, for instance, is an important player in Brazil, it is the same for Engie (the largest private company generator in Brazil) and Enel. Those three companies belong to the list at figure 2 bellow which characterizes the 25 biggest electricity sector operations in the world by total revenue in 2015.

Figure 2: The 25 biggest Electric Utilities. Source: Frei et al (2018)

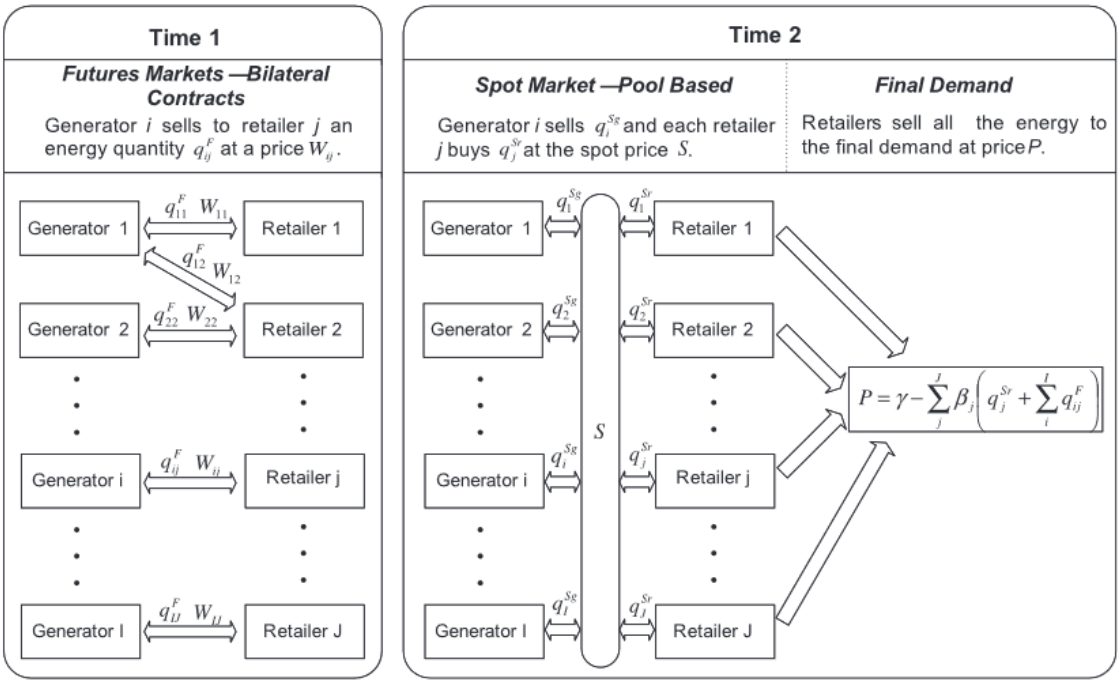
Code	Company	Country	Total Revenue 2015 in M USD
HPI	Huaneng Power International Inc.	China	19,855.65
HPIC	Huadian Power International Corporation Ltd.	China	10,938.63
DIPG	Datang International Power Generation Company Ltd.	China	9,533.17
EDF	Electricite de France SA	France	81,456.54
Engie	Engie SA	France	75,892.96
E.ON	E.ON SE	Germany	126,212.79
RWE	RWE AG	Germany	50,343.72
EnBW	EnBW Energie Baden Wuerttemberg AG	Germany	22,986.83
Enel	Enel S.p.A.	Italy	79,360.56
Edison	Edison S.p.A.	Italy	12,285.92
A2a	A2A S.p.A.	Italy	5,344.21
TEPCO	Tokyo Electric Power Company Holdings Inc.	Japan	53,926.15
Kansai	Kansai Electric Power Company Inc.	Japan	28,837.12
Chubu	Chubu Electric Power Company Inc.	Japan	25,355.76
Korea EPCO	Korea Electric Power Corporation	South Korea	50,178.92
EDP	Energias de Portugal SA	Portugal	16,851.25
Iberdrola	Iberdrola SA	Spain	34,120.71
Enedesa	Endesa SA	Spain	22,044.72
Acciona	Acciona SA	Spain	7,106.27
SSE	SSE plc.	UK	41,323.94
Centrica	Centrica plc.	UK	41,223.55
National Grid	National Grid plc.	UK	21,701.99
Exelon	Exelon Corporation	USA	29,447.00
Duke	Duke Energy Corporation	USA	23,459.00
Southern Co	Southern Company	USA	17,489.00
		Total	907,276.37

The unbundling process which had transformed sector monopolies into oligopolies, also created two different regulated markets. It separated generation market from transmitter and distribution, whose comprehend natural monopoly regulatory norms. (Gluger et al, 2017), (Filippini and Wetzel, 2014).

Electricity Supply Chain has two kinds of contracts and coordination design among generators to distributors. It can be bought 100% in auctions between generators and retailers or it can be partial bought in auctions (Oliveira et al, 2013). Brazil for instance allows companies that consume more than 3000 KW to do deals directly to the generators, paying the retailer only the use of distribution lines. Other clients pay to retailer also the energy that was bought in an auction.

The energy bought through auctions can be future bilateral contracts or short-term contracts, this last one called Spot Market (Oliveria et al, 2013). It means that price and quantities are always contracted before the real consume. In Brazilian case, the risk of stay without or with surplus energy is majority uprooted in retails unified plan. A retailer can stay 1% below the consumed plan contracted to 5% over contracted and clients will pay for it, however more or less than it, retailers must pay off the risk. In the figure 3 it is represented only generators and retailer, lacking information about transmitter. It is due to the transmitter be considered with no possession of the energy, it only delivering it to the retailer.

Figure 3: Optimization of Electricity Supply Chain. Source: Oliveira et al (2013)



The early upstream tiers are very important for the coordination, design and strategy of the whole energy supply chain, which has the main objective to attend picks of demand, to guarantee more energy than what it is demanded and now to be transformed into a low carbon emission system, objectives cited in Gluger et al (2017). Developed market still dependent of fossil fuels and coal to produce energy. It means the stock available in the whole energy chain, it is the stock of gas, coal and uranium. To replace it for water, sun, geothermal, wind and others renewable energies is a complex process of replacing and restructuring most part of the conventional supply chain electricity into an economy of abundance and it takes time, money and conflict of interest. Those first ties also provoke a reverse logistics from production to waste. A comprehensive SCM can be seen in Sanderson (1999) and in Liboni et al (2018)

Figure 4: Comprehensive SCM. Source: Sanderson (1999)

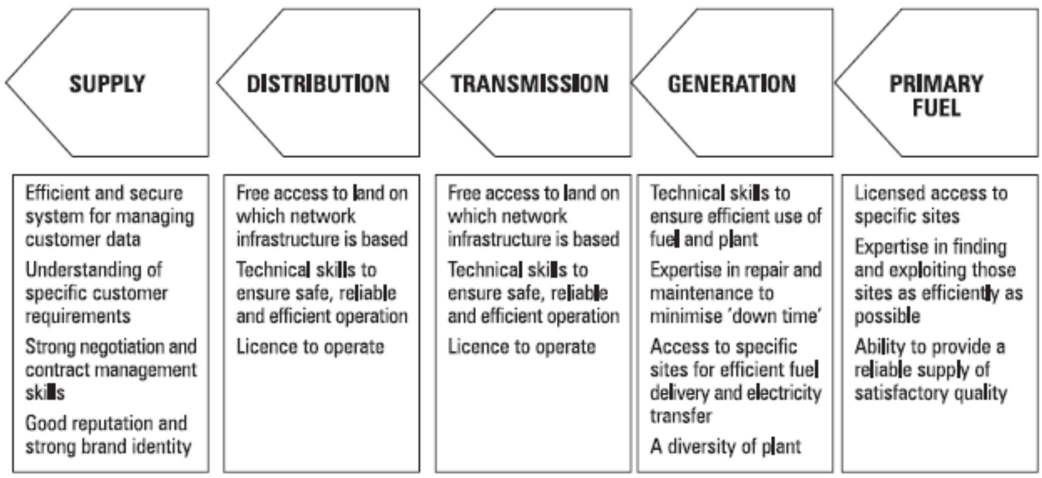
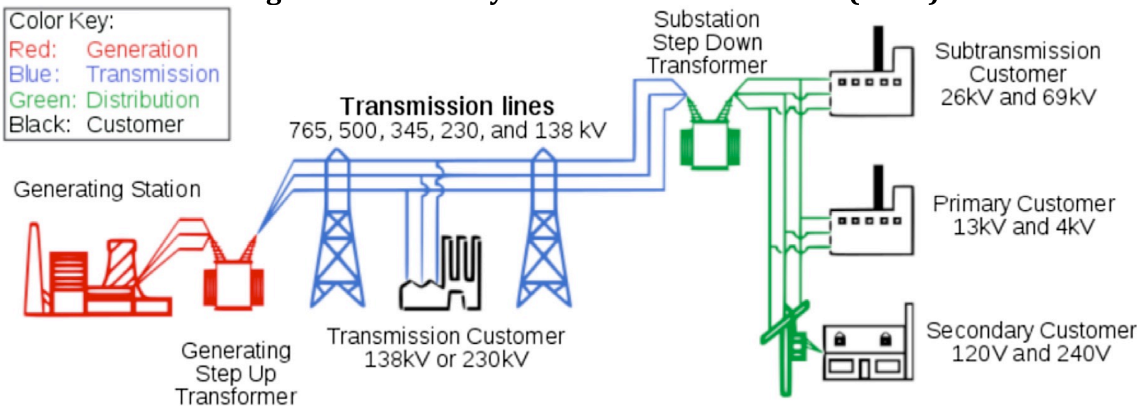


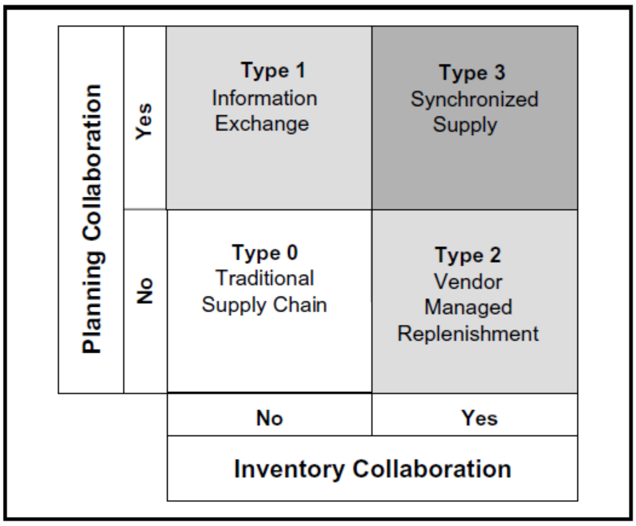
Figure 5: Electricity Grid. Source: Liboni et al (2018).



SYNCHRONIZATION, LEAGILITY, COLLABORATION AND ELECTRIC UTILITIES

In normal Supply Chains, stock and sock-out which the last one considered impossible to be acceptable are elements that give integration and synchronization signals. A push demand system without information flow coordination, and planning and inventory collaboration is considered a traditional supply chain. Once the level of information sharing about planning and inventory increases, it generates integration and synchronization through demand pull systems. (Holweg et al 2005).

Figure 6: Synchronization. Source: Holweg et al (2005)



Electricity markets have at least three important characteristics. Their demand is "broadly inelastic, retailers cannot curtail demand, and output is no storable" (Aid et al, 2011). A synchronization with those peculiarities implies in a strong planning collaboration induced by a central government regulation body which can enable zero energy blackouts or, at least, a minimum blackout acceptable. Brazilian electric energy national agency (ANEEL) puts strong monitoring on energy electric interruption and it can indeed cancel the license for exploring energy distribution, forcing a taken over.

Beyond synchronization, a normal supply chain can be Lean, Agile or Leagile. A Lean Supply Chain and Procurement is concerned about eliminate waste while Agile is dedicated to transform the organization in a virtual corporation to cope with high demand variation. Leagile is a combination of both where it has, for instance, a decoupling point and a postponement movement, letting a part of chain to deal with elimination of waste and, the other, to attend high variation on demand. (Naim and Goslin, 2011) (Drake et al, 2013). Products characteristics are critical to the success for choosing methods. Figure 7 differentiates a functional product (better with Lean) to an Innovative Product (better with Agile).

Figure 7: Functional and Innovative Products. Source: Drake et al (2013)

	Functional products	Innovative products
Life cycle	Long	Short
Variety	Low	High
Volume	High	Low
Demand	Stable/predictable	Volatile/unpredictable
Production driver	Forecast	Demand/customer-order
Manufacturing strategy	MTS	MTO
Production control	JIT/Kanban	MRP
Average stockout rate	Lower	Higher
Components	Standard	Standard and specific

Other important differentiation is Fisher framework cited in Birhanu et al (2014), which was able to understand that SCs does not choose their designs by the product type, rather they are influenced by the demand size characteristics. In general, what Fisher considered efficient is "roughly equivalent" to Lean, and what he had nominated responsiveness is "roughly equivalent" to Agile. Birhanu et al (2014) showed a figure where is possible to take some parameters to define if a SC is Lean, Agile or Leagile. It must be remembered that a SCM can be traditional which is normally a mass production system within a push demand system.

Figure 8: Fisher Framework Adapted. Source: Birhanu et al (2014)

		Demand Uncertainty	
		Low (Functional products)	*High (Innovative Products*
Supply Uncertainty	*Low (Stable process)*	Grocery, basic apparel, food, oil, & gas	Fashion apparel, computers, pop music
	High (Evolving Process)	Hydro-electric power, some food produce	Telecom, high end computers, semiconductor

Figure 9: Fisher Framework Adapted 2. Source: Birhanu et al (2014)

		Demand Uncertainty	
		Low (Functional products)	*High (Innovative Products)*
Supply Uncertainty	*Low (Stable process)*	Efficient SCs	Responsive SCs
	High (Evolving Process)	Risk-Hedging SCs	Agile SCs

In an electricity supply chain, electricity is more a functional product than an innovative one. Although it has no JIT and KANBAN systems (zero stock once the electricity is generated), it is a well-integrated supply chain with regulation government body looking for the whole chain equilibrium. It has a high-volume delivery, a predictable demand, and it tries to have a small average stock-out (zero blackouts). It has also special supplies of oil, coal and gas which are totally functional products. The main goal of an electricity supply chain is two: efficient SCs and Risk-Hedging SCs. As it has been commented above efficient is roughly equivalent to Lean, and an important goal to electricity supply chain is eliminate non-aggregated value and to avoid waste. Risk-hedging SCs works for hydro-electricity where an important component for demand forecast is uncertainty (in this case rain fall quantity).

ELECTRIC UTILITY 4.0

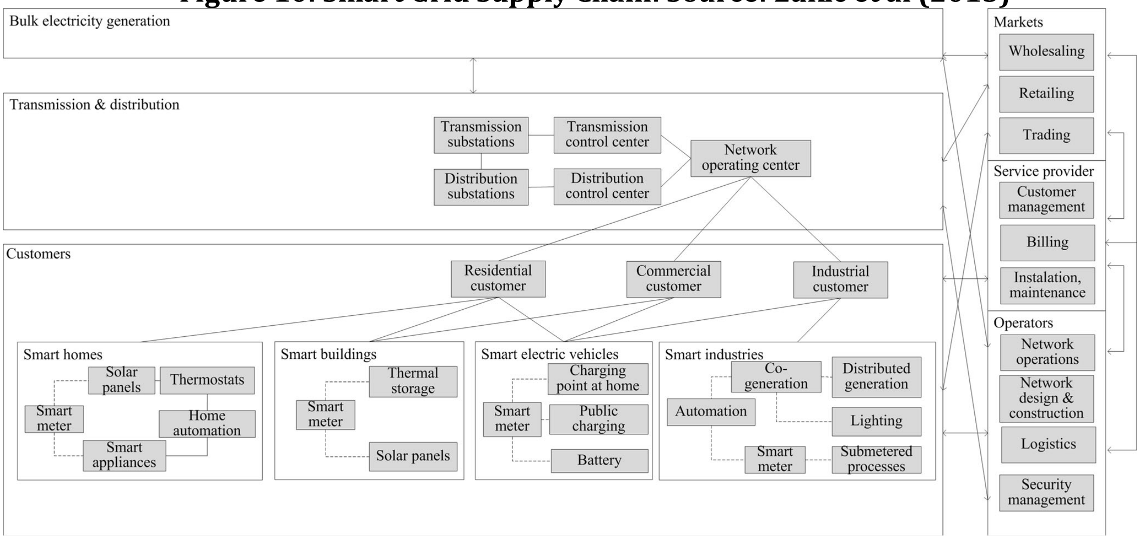
Each Industrial revolution has the capability of changing on, at least, five special points: locomotion ways (cars, train, airplane, etc.); industrial technology (steam mechanical, electrical, combustible mechanical, 3D print, robots), business environment (improvement of regulations, labor conditions), energy power (stem, coal, gas, oil, renewables) and communication (telegraph, telephone, internet, mobile phone, smart tv). Tien (2012) affirmed that this industrial revolution, he called the third one, is one that integrates services and industry.

However, most scholar are calling it as industry 4.0 or the fourth industrial revolution, the one that integrates “IOT (internet of things) into the production and manufacturing environment” (Tjahjono et al, 2017). It is bringing the electrical autonomous car and drones (locomotion ways), introducing more dependency of renewable electric energy (energy power/industrial technology), creating an interactive media (communication), developing new labor regulations, introducing robots in repetitive services, incentive to “knowledge era” (business environment) and to digital supply chains, defined as utilization of real-time information (Büyüközkan and Göçer , 2018). Industries have tried to cope with that revolution and it is not different to electric utilities (Liboni et al, 2018).

One important innovation to electric utility is the Big Data. It has no a clear definition (Addo-Tenkorang and Helo, 2016), but it has been widely used, what will need more specific tools (Tiwari et al, 2018). Big Data allows electric utilities to orient their business through a comprehensive amount of data. Brinch (2018) informs that Big Data is a now way of doing business “enhanced by logic, facts and evidence”. Gunasekaran et al (2018) remembered some features of a Big Data: “high volume, velocity and variety”. A utility has some information about energy consumption, distribution statistics, weather correlation with energy blackouts, and others. To deal with Big Data not only improves the service provider to end-consumer, but it also generates new business opportunities to sell services for small and medium size companies which urge for more data.

Maybe the most important technology for electricity supply chain is the smart grid and the smart meter. Those are consequences of Internet of things, “system in which the material world communicates with computers (exchanges data) with ubiquitous sensors” (Witkowski, 2018). Those sensors generate the Electric Power Big Data (Wen et al, 2017). Lukić et al (2015) presented a model for a Smart Grid Supply Chain.

Figure 10: Smart Grid Supply Chain: Source: Lukić et al (2015)



Another important change is the distribution generation, aligned with renewable sources, PV (photovoltaic panels), wind, waves, geothermal and others. It does not only take out certain stocks of coal, gas and oil for an uncertainty knowledge about sunny days, rainy days, windy days and others, but it does something even bigger. Maybe the most challenge for next decade is to decentralize even more the production from an oligopolies format to a self-production capability decentralized to end-consumer energy production.

CONCLUSION

This paper presented a definition of supply chain management as a network. It gave as an example the Electricity Supply Chain which is a complex network commonly coordinated by a regulatory organism where the plan and the risk stay with the natural monopoly of energy retailers. It was also commented that Electric utilities are passing through a deeply revolution which is allowing consumers to produce their own energy. More than that, the industrial revolution is increasing consumption and dependency of energy.

This scientific paper was able to find some important definitions for supply chain. However, it is necessary to find some information about Electricity Supply Chain, specially about that 4.0 industry where it will be possible to define if future Electricity Supply Chain can become an Agile Supply Chain, using virtual networks. For now, as electricity is a functional product, it can be said it is more a Lean or even a mass production series, but one that must combine production with distribution.

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