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ENERGY SUPPLY CHAINS –TRENDS AND CHALLENGES OF GROWING ENERGY DEMANDS, ENERGY EFFICIENCY, ALTERNATIVE ENERGY RESOURCES AND ENVIRONMENTAL SUSTAINABILITY

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ABSTRACT: Energy supply chains are complex technological and economic structures that can be considered at different levels of their functioning. In this paper, energy supply chains are considered at the national economy level and in the context of wider supply chains of the region they belong to and that has precisely defined participants and relations within energy chains and their mutual relations. Trends in the development of energy supply chains were considered in the context of strategic development of other supply chains, whereby similarities and differences were detected. Evaluation of key development aspect and trend estimation of energy supply chains in the Republic of Croatia was performed. To get better insight in SC trends of analysed sector the analysis is spread out with SWOT analysis.
KEYWORDS: energy supply chains, trends, SWOT, Croatia

INTRODUCTION

Supply chains in the energy sector are complex technological and economic structures functioning as infrastructure to other supply chains for goods and/or services. Functioning of other supply chains is not possible without them. For this reason supply chains in the energy sector are of special significance at business, sector, national, regional and global level. Development of the energy supply chain has strong impact on the nature as well as the quality, efficiency, technological base and competitiveness of all other supply chains.

The fact that SCM as complex term is not firmly and widely accepted in energy sector has its historical origin. Namely, the key activities in energy supply chain (exploitation of primary resources, production, transmission (transport), distribution and supply of final consumer) in Europe (as well as in most other countries) were performed by one or two state owned companies (in Croatia HEP and INA) and those companies as well as state for itself, has no any interest to divide their processes and make them visible [1].

After the claims of private sector to participate in energy SC processes the restructuration (demonopolization) of those systems begun. Those systems that start earlier with reconstruction, has recognised the need to introduce new terms like are SCM in newly established partners and relationships [2].

A typical supply chain in the energy sector begins with the so-called primary forms of energy, that is, naturally occurring forms of energy for which there are acceptable technological systems for their gathering, transformation into other forms, transmission, distribution, storing and use.

From the aspect of the initial primary resource, there are several supply chains [3]. For example, hydropower, wind energy, solar energy, nuclear energy, wave and tidal energy are converted into electrical energy and used for different purposes by end users (economic operators, public sector and households for heating, cooling, power of stationary engines, lighting).

Energy from fossil fuels (coal, oil, gas, oil shale and biomass) is mostly used in two typical supply chains: energy originating from coal mainly ends up in the supply chain of electrical energy through technological systems of thermal power plants. To a lesser extent it is used by end users in direct production of heat (industrial and personal consumption).

Oil (petroleum) is not directly used in production of energy. Physical processes are applied to decompose it into components (gases, petrol, diesel fuels, bitumen…) that are mostly used in supply chains ending in a type of internal combustion engine that is mostly used to power transport systems.

Smaller part of the so-called heavy derivatives that are unsuitable for internal combustion engines is usually converted (through heat processes) into electrical energy and/or immediate generation of heat that is distributed to end users.

In the current technological systems it is most economical to convert natural gas into heat energy through transformation system at the place of end

users. In special condition (price of NG, demands for electricity, available technology) natural gas is used also in thermal power plant.

A significant share of oil and gas is used in petrochemical (non-energetic) processes as raw material base for production of numerous chemical products (greases, petrochemicals, artificial fertilisers...)

Energy supply chains face several challenges, including:

- *A constantly growing demand for all forms of energy and a constantly growing price of energy,*
- *New technological solutions in exploitation of natural forms of energy, transformation, transmission, distribution and consumption of particular forms of energy,*
- *Strong pressure on efficiency in exploitation, transformation, transmission and consumption of energy*
- *Pressure by means of demands for preservation of the environment which is endangered in all phases of the energy supply chain, and introduction of new forms of trade - trade in unused pollution rights in the global environment,*
- *Globalisation of energy supply chains resulting in a complex architecture of supply chain networks that have to be efficiently managed,*
- *Energy supply chains are strongly regulated by means of state (political) influence, and deregulation (liberalisation) is carried out in the way that new participants appear in the supply chain (especially in distribution and supply systems),*
- *Internationalisation of the energy sector is becoming more widespread,*
- *New participants and new roles in the supply chain appear to carry out deregulation and demonopolisation of the energy market, control and envisage consumption and ensure investment cycles in the energy industry,*
- *Increased visibility of processes and distribution of risk in the supply chain among all participants*
- *The key problem of harmonizing supply and demand for particular forms of energy is of dynamic character, changing at daily, weekly and monthly level as well as seasonal level (depending on weather conditions). Penalisation due to discrepancies among production, distribution and consumption tends to be fair, forcing participants to carefully plan consumption and stimulate expansion of production and distribution capacities as well as to open the market to international competition.*

The aim of this paper is to estimate future directions of development of the energy sector as a complex chain of energy procurement by providing synthesis of trends in energy supply chains and trends in SCM.

GENERAL TRENDS OF BUSINESSS SYSTEMS IN THE FIELD OF SCM

Trends in the development of SCM systems were evaluated from different aspects, depending on the area they belong to, participants included, the period that the trend evaluation refers to and the significance given to particular aspects of SCM. Parallel analysis of trends in the development of energy supply chains was carried out in relation to the trends of SCM companies presented in the paper Global supply trends 2010 -2012 [4].

Although energy supply chains have specific qualities in terms of participants, their activities, products, processes and cycles, some key patterns of behaviour of SCM systems in other fields can be also recognised in the energy supply chains. These patterns were used for evaluation of trends in the development of energy supply chain systems in the Republic of Croatia.

The following trends were investigated:

- *Increased supply chain uncertainty and volatility,*
- *Globalisation of supplier and buyer networks,*
- *Market dynamics and configuration of regional and cost-optimised supply chains,*
- *Risk management in the entire supply chain,*
- *The level of integration of SC participants in energy SC.*

Directions of development of SCM in energy supply chains were evaluated based on selected trends. Behaviour of SC chains in the energy sector in the past will be investigated below as well as trends expected in a relatively close period of their future development.

TRENDS EVALUATION

A set of chosen trends should provide an insight into key aspects of future development of energy supply chains.

Increased supply chain uncertainty and volatility

This trend is increasingly present in the energy sector, as deregulation introduces a significantly larger number of participants on the supply side [5]. In this way market becomes more transparent and sensitivity to product prices leads to reduced loyalty of buyers. These phenomena resulted in new prognostic methods providing forecasts on daily, weekly, and monthly level as well as new market models and new supply models.

Mutual requests of producers, transmitters and distributers as well as all listed participants toward their end users have produced new generations of buyers (privileged buyers, tariff buyers; large buyers, medium-sized and small buyers) and new types of competitive relations and contractual relations in energy supply chains.

Whereas the focus of dominant strategies was on internal organisation until recently, dominant practice in the future generation of energy SCM will be focused on key suppliers and key buyers [6].

Although it is considered that price sensitivity of energy in general is low, the share of energy consumption in the total household consumption is on increase in terms of value, but in material sense it stagnates or is mildly growing, which indicates the fact that small consumers are sensitive to price of energy-generating products [7].

Globalisation of supplier and buyer networks

Energy market is highly internationalized due to the distribution of natural energy resources. Every state or even state association will tend to provide as much as possible energy from domestic resources and all

surplus sell on world energy market. On the other side, energy importing economies will try to make such agreements with exporters that guaranty supply continuity and reliability and adequate prices. This is why energy supply chain need highly developed supply chain network.

Energy supply chains are internationalised systems with the largest multinational companies on the production and transmission side as well as the distribution and supply side, mostly private or state-owned companies with huge concentration of capital and power.

These business systems were restructured following demand for deregulation of the energy market and their restructuring was carried out with the primary objective to manage the entire energy supply chain as efficiently as possible. New companies appear in the sphere of distribution and supply that do not necessarily need to have large capital. They also do not need to have physical infrastructure in which supply chains take place and they take over the role of a trader in the supply chain. This means that in a limited period of time (but also permanently) and on limited area they can buy and sell energy, utilising benefits occurring both on the supply and/or demand side. In addition, intermediaries appear in the supply chain, selling information or other types of services to real participants in the supply chain.

To maintain balance between supply and demand in circumstances of high energy dependence (like is the European energy market, but also on the markets of most of the developed countries in the world) and fluctuation on the global energy markets in the long run, participants in the supply chain must have high financial and negotiating strength.

Managing a supply chain in internationalised energy markets makes it possible for participants with greater market strength (those with more complex and longer chain) to achieve higher competitiveness on local national markets and to expand to other local national markets.

Development of energy structure (building of new capacities and stimulation of new, so-called privileged buyers) has been envisaged in the price of energy-generating products, which means that participants in a supply chain that is expanding will also build infrastructure and capitalise it through their own future activities and concessions.

Market dynamics and configuration of regional cost-optimised supply chains

Participants in energy supply chains in the European energy systems define mutual contractual relations whose aim is to provide a stable, reliable, foreseeable and manageable energy system that will also be acceptable in terms of development.

In the circumstances where national markets depend on energy import, supply chains need to be optimised in terms of minimising total costs of energy supply for the entire supply chain. Cost minimisation on the side of end consumers reflects in:

- Accepting demands for building energy efficient facilities in which there will be no drastic changes in demand if environmental conditions change,
- Introducing intelligent electrical installations (for example, EIB - European Installation Bus [8]) that will rationalize consumption in private, public and industrial facilities,
- Introducing automated systems for regulation of fuel consumption (natural gas),
- Using devices and appliances that consume less energy and/or use it more efficiently,
- Using optimal transport routes, means of transport, and vehicles with reduced fuel consumption,
- Selecting the most energy efficient industrial plants,
- Electronic devices are used in electrical energy distribution systems to compensate reactive power,
- Process automation - Automated business rules are used to define the set of critical business events and to propose problem solutions to the owner in real time [9].

Regulations pertaining to the above requests are partially in place (energy performance certificates for facilities, energy performance certificates for appliances and equipment, fuel consumption and stationary engines tests), thus stimulating savings or penalizing irrationalities in final consumption.

Rationalisation of transmission systems in terms of savings is based on introduction of electronic and control and regulatory systems whose main purpose is to adjust and reduce losses in transmission. New technological solutions are expected in application of new conductors and transmission of higher power at lower costs.

In production, i.e. transformation of primary forms, considered in the short-term period, savings will be lowest, as the technological structure of production plants is relatively unchangeable. New generations of nuclear and thermal power plants are focused on more efficient use of primary forms of energy, but there are strong requests regarding their safety and environmental impacts.

Through the process of the energy market deregulation, complex energy systems (national energy companies) were decomposed into separate operators in the field of production, transmission, distribution and supply. Supply chains established after deregulation may appear fragmented and under-optimised. However, their real integration and necessary optimisation has started with consistent energy policy at the EU level and by accepting the agreed directives [10].

Risk management in the entire supply chain

Supply chains in the energy sector are exposed to various risks. These risks arise from:

- Inability to predict weather conditions and their instability, with risks both on the side of consumption and production,
- Inability to predict political circumstances in the countries supplying primary forms of energy (natural gas, oil),
- Relations with neighbouring countries
- Decreased purchasing power of final consumers in the economic crises

- *Drastic increase in the price of primary energy sources and inability of domestic primary producers to obtain sufficient quantities of required primary forms of energy,*
- *Introduction of new financial burdens due to environmental requirements.*

The above risks, as it can be seen, can appear in different parts of a supply chain and the problem of managing these risks has to be divided among supply chain participants in a way that is as fair as possible. Special attention in risk management of supply chains is given to the following strategies, on which also SCM systems in the energy sector will be focused:

- *Efficient management of reserves. In the energy sector this means that at the national level the so-called mandatory reserves are maintained in an amount corresponding to three months of consumption,*
- *Profitability and cash flow management,*
- *Reduced pollution in all phases of the supply chain (reducing CO2 footprint),*
- *Optimised management of incoming and outgoing receipts (by introducing complex ERP and SCM computer systems, for example, SAP in energy, gas and oil sector in the Republic of Croatia, providing fast retrieving and processing, which resulted in strong financial discipline on the energy market),*
- *Improved quality, safety and reliability of products.*

The level of integration of SC participants in the energy SC

Energy supply chains are internationalised systems with the largest multinational companies on the production and transmission side as well as distribution and supply side that are private or state-owned companies with huge concentration of capital and power. Energy supply chains in the Republic of Croatia comprise the existing organizations that are organized according to energy legislation packages. The key piece of legislation is the Energy Act [11], whereas a particular energy market (electricity, gas, oil) is regulated by separate regulations, bylaws and conditions for energy supply. Market is functioning according to selected models. Models determine participants, their activities and relationships in the supply chain.

Following deregulation processes, integrated, complex, monopolistic and very often inefficient state-owned companies in the European energy space were transformed and some new companies were founded in the private sector that take over some of the possible roles in energy supply chains. In addition, also companies were founded whose primary function is monitoring and regulation of energy supply chains as well as providing direction for energy development (HROTE, HERA [12]). Although energy supply chains are relatively firm organisational and technological structures with clear roles in supply, participants in the energy market still do not create a fully integrated supply chain.

On the side of end users transition should be completed toward the so-called smart grids, which will provide two-way communication between consumers and suppliers as well as their more active and more complete participation in the energy market. Increasing share of alternative energy sources in the supply system may increase system variability. Therefore some of the following adjustments should be made:

- *Introduction of "Fast markets" (fast markets - contracting delivery during the day, for example, three hours in advance) along with good forecasts;*
- *Building of flexible power plants (hydro power plants, reversible hydro power plants, gas power plants) that can quickly regulate changes in the power);*
- *Storing energy at the level of both transmission and distribution networks (batteries, fly-wheels, fuel cells, super-condensers);*
- *Consumption management;*
- *Interconnections contributing to system and market expansion, thus decreasing variability at the level of (larger) system. In addition to interconnection lines, to achieve the desired effects it is necessary to define market rules to allow optimal utilisation of interconnection lines [13].*

SWOT ANALYSIS OF CROATIAN ENERGY SECTOR

Analyses in previous parts highlighted Croatian energy sector as complex supply chain. In addition we give simple SWOT analysis to make this economic sector clearer in the context of its future development.

Strengths:

- *Potential of oil and gas explored and those already in exploitation*
- *Existing energy infrastructure (pipelines, electricity distribution and transmission systems, heating systems)*
- *Experiences in investigation of new oil, gas and thermal sites*
- *Experiences in projecting and managing complex energy systems*
- *Excellent climate and geographic potential for renewable energy sources (solar, wind and geothermal)*

Weaknesses:

- *Relatively old technological infrastructure of energy plants (hydropower plants, heating plants and cogeneration plants)*
- *Shortcomings in infrastructure needed for takeover of electricity made in small photovoltaic and hydropower systems*
- *Not completed regulation in energy sector*
- *Insufficient number and technically equipped SME-s for high quality distribution and maintaining of energy (electricity)*
- *Inadequate information infrastructure*
- *Low level use of unconventional energy resources*
- *Discrepancies in energy prices for home and industrial users and still active state price regulation*
- *Shortcomings in own investment potential for new resources exploitation and increasing energy efficiency*

- *Higher energy intensity then EU27 average (energy intensity is relation between total energy consumption and GDP)*

Opportunities:

- *Excellent climate and geographic potential for renewable energy sources (solar, wind and geothermal)*
- *Preservation of ecological environment due to small consumption per capita*

Threats:

- *Dependency on foreign energy resources is going to increase*
- *Electricity is dominantly based on hydropower which depend on weather condition*
- *Insufficient refinery capacity and their technology obsolescence*
- *Entry of new producers and distributors on the energy market*
- *Dependency on political relations in the oil export countries*
- *Priorities and interests of foreign owners of Croatian companies*

CONCLUSIONS / FINAL CONSIDERATIONS

Despite specific qualities of energy supply chains in relation to other supply chains, in strategic considerations they follow trends of other supply chains, i.e. companies with focus on SCM to a great extent. Deregulation of the energy sector has made energy supply chains more visible in their structure, functions and mutual connections, irrationalities and monopolistic characteristics. Deregulation has produced disintegrations, accelerated technological progress in all phases of the supply chain. Market characteristics of European, i.e. particular national energy supply chains have resulted in demand for plenty of innovations and rationalities in energy supply chains. Necessity of efficient management has evoked the need for integrations and collaborations on new technological bases and with new short-term and long-term goals. A clearer distribution of roles and tasks among participants in the supply chain has made their monitoring, control and directing possible already now, and this will become more pronounced in the future.

Growing internationalisation and globalisation of energy markets has lead to creation of new integrations, with the goal of strengthening negotiation positions of energetically dependent national and private energy systems.

Finally, it can be concluded that investigated trends of energy SCM correspond to trends of SCM firms. This is why principles of SCM firms will be accepted in energy sector, but it is also to expect that some principles (especially automation) of energy SCM will be outspread in other SC-s.

To get better insight in SC trends of analysed sector the analysis is spread out with SWOT analysis. SWOT analysis has only limited analytical strength and need to be broaden with links and relations of present and future state of analysed system.

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