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TOWARDS A RESILIENT ENERGY SYSTEM IN EASTERN ROMANIA – FROM FOSSIL FUELS TO RENEWABLE SOURCES

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Abstract: The study takes into account the two Romanian Eastern regions (North East and South East) trying to emphasize the post-communist dynamics of the energy sector in order to draw a general perspective for the future evolution towards both energy security and a clean environment. Before 1989, the energy sector, that had to sustain not only the population needs, but also an oversized manufacturing industry, was based on big power plants usually using coal and oil and highly polluting the environment. The hydropower had a rather small share in the total energy production. This inherited system was very much resistant after the end of the centralized political system, therefore after the general industrial decline the energy sector remained the main source of air pollution in many towns and cities from Romania. Meanwhile, in the last 6-7 years, due to a favourable national political context, we assisted, especially in the analysed area, to an important emergence of renewable energy investments (mainly wind and solar energy, but also biomass or hydro-energy). Our purpose is to evaluate, from a geographical point of view, the extent and the implications of a desirable progressive shift from fossil fuels to renewable energy that could radically change the territorial relations and sustain development on the long term.

Key words: renewable energy, regional development, energy government policy, spatial resilience

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INTRODUCTION

Resilience can be defined as a measure for the persistence of systems and for their ability to absorb changes and disturbances while maintaining their fundamental relations between the essential elements (Holling, 1973), but also as the ability to absorb variations by efficiency, functional diversity, variety, redundancy and by providing flexibility reserves (Molyneaux, 2012). The term resilience also refers to the ability of a system, region, community or person to respond

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and adapt to rapid changes, to absorb external shocks and to mitigate the impact in order to ensure that sudden shocks and stresses will not necessarily lead to a long-term decline, but that they are able recover quickly (Hill, 2008; Pike, 2010; Mitchell, 2012; Bigos, 2013; Martin, 2012).

The concept of territorial resilience (Hambouch, 2012) states that the answer a complex ecological system can give to sudden changes in the environment is expressed in at least two manners: first the *static resilience* when the system has a capacity of self-organization, adaptation and (defensive) resistance to change, which allows it to maintain, by retaining its original shape and specificity (for e.g. the existence of its own resources of coal and natural gas) and secondly the so-called *dynamic resilience*, characterized by an ability of the energy system to adapt, learn, transform and re-create, which ensures its ability to adjust to external shocks.

This approach opens a wide range of interpretations. Thus, one can distinguish between *ecological resilience „emphasizes conditions far from any steady state condition, where instabilities can flip a system into another regime of behaviour”* (Gunderson, 2000), *engineering resilience „concentrates on stability at a presumed steady – state and stresses resistance to a disturbance and the speed of return to the equilibrium point”* (Pendall, 2010), *regional economic resilience „the ability of a region to recover successfully from shocks to its economy that either throw it off its growth path or have the potential to throw it off its growth path but do not actually do so”* (Hill, 2008) or *labour market resilience „the ability to transform regional outcomes in the face of a challenge”* (Chapple, 2010).

The resilience of such a complex system depends on certain internal features, but also on the amplitude of the disturbing phenomenon to whom it is subjected to and on its relations with the environmental components (Drăgan, 2011). The energy system is a fundamental component of the economic system of any country (Bădileanu, 2014; Bădileanu et al., 2014). In order to minimize the impact of dysfunctionalities within the economy an acceptable level of resilience is needed, namely a functional redundancy to provide opportunities for adaptation of viable solutions, while a preliminary solution is represented by the increase in energy efficiency and a higher use of renewable energy (Duşmănescu, 2014; Câmpeanu, 2014; Colesca, 2013).

OBJECTIVES AND METHODOLOGY

The study aims to apply the theories related to resilience in case of a complex system such as the national energy system, which integrates natural components (fuel resources, both classical or unconventional) and anthropic elements- economic (infra)structures such as thermo power plants, hydroelectric facilities, wind plants or solar energy facilities etc. The integrated analysis of the two (natural and economic) systems allows a study of interactions between them, while evaluating their resilience capacity when operating within a complex system with numerous interdependencies.

The paper proposes the delimitation of the basic traits of Romanian energy system resilience with reference to the contribution of its eastern regions, as well as evaluating the dynamics of classical energy sector and the emergence of renewable energy in the North East and South East Regions. The second objective is to measure and analyse disparities between different regions and evaluate the contribution of the analysed territorial subsystem to accomplish specific objectives of the national energy strategy.

Finally, the purpose was to establish to what extent the *„green revolution”* and the continuation of current trends is sustainable on the long term and whether it is able increase the resilience of the energy system as a whole. In this research there several types of indicators were chosen (based on data from the National Statistics Institute) in order to illustrate the assumptions and to obtain relevant results: from the energy vulnerability index (Ive) and the capabilities of large combustion plants, to the dynamics of renewable energy investment for the period 2007 - 2013. The analysis was made both at local and county level, therefore mapping and interpretation of derived indicators can explain the current situation of the existing national energy system.

RESULTS AND DISCUSSIONS

The resilience of the National Energy System

The resilience of energy systems can be explained by following the four typical stages of a system subject to external influences: challenge, context, response and outcome (Hamdouch, 2012). The starting point is the *disruption* or *initial shock* that triggers certain response mechanisms. For an energy system it may include decreased availability of fuels in case of shocks, increasing prices, the introduction of environmental restrictions, reducing imports of electricity, unexpected changes in demand. The second concept - *the context* - refers to the fundaments that structure and shapes the national energy system, i.e. the state energy policymaking process, the functioning of the institutions, the overall economic situation.

The third stage, *the answer* should be understood as the moment when the system adapts to existing challenges i.e. the ability to absorb innovation and structural rearrangements of energy producing and distributing facilities. Given the current technologies, an adequate response involves the replacement of polluting energy producing units by those using renewable energy sources, more *environmentally friendly* and much more suitable in order to eliminate some of the pollution from power plants. The final concept is *the result*, which can consist either by the returning to the initial situation (pre-shock phase) or by improving/worsening the functionality of the system. In other words, it is necessary to determine whether the national energy system was deeply affected or recovered well, by minimizing costs and by maximizing energy production profits.

During the communist period, in Romania, an intensive process of industrial development took place, based on systematic exploitation of natural resources, without seriously taking into account the environment effects. In the first phase (years 1950-1960) equipping the territory with basic infrastructure elements (electrification, hydro, roads etc.) started together with the allocation of massive investments in mining activities and heavy industry (steel, shipbuilding). Years 1970-1980 marked a change in national development policy by moving to the implementation of more diversified highly intensive industries (aluminium, machine building, chemical and petrochemical industries).

The last stage of the communist period (1981-1989) is marked by a new vision in socio-economic territorial units distribution aiming to obtain homogenization in development, which involved, among other things, the construction of industrial giants, big consumers of labour force and energy, but often characterized by economic profitableness and representing major sources of complex pollution. Simultaneously, it was necessary to develop a high capacity energy sector to fuel this oversized processing industry, but also to meet the direct needs of our growing population. Large units of electricity and heat production were built by using hydropower potential (by building huge artificial reservoirs with multiple effects on the natural environment and the local settlements) and nuclear potential (with corresponding risks included) but most of the energy demand was satisfied by installing high capacity thermoelectric power plants using huge quantities of fossil fuels by sometimes deficient technologies increasing the concentrations of pollutants, that were added to those generated by the processing industry.

After the fall of the communist regime, the transition from a centralized economy to a market economy has been accompanied by a clear decline in productive activities (many industrial units disappeared, including most of the factories and large industrial complexes), which resulted in the decreasing of the overall energy consumption in industry (figure 1). For example when Romania confronted the peak of privatization and closure of large industrial facilities the industrial energy consumption decreased from 13.68 million kWh (1996) to 10.208 million kWh (2000) (Bădileanu, 2014).

From 2007, the integration of Romania into the European Union led to the adoption of the Community acquis, i.e. the EU directives on air quality and other environmental fields. Regarding the energy industry - the main remaining consumer polluting of fossil fuels (figure 2) – one can notice the maintaining of large units especially in South-Western Region and the relative diminishing activity of power plants in urban areas, due disconnection and the proliferation of individual sources heat production. Nowadays, the overall level of energy consumption in Romania stands at less than one third compared to the EU average.

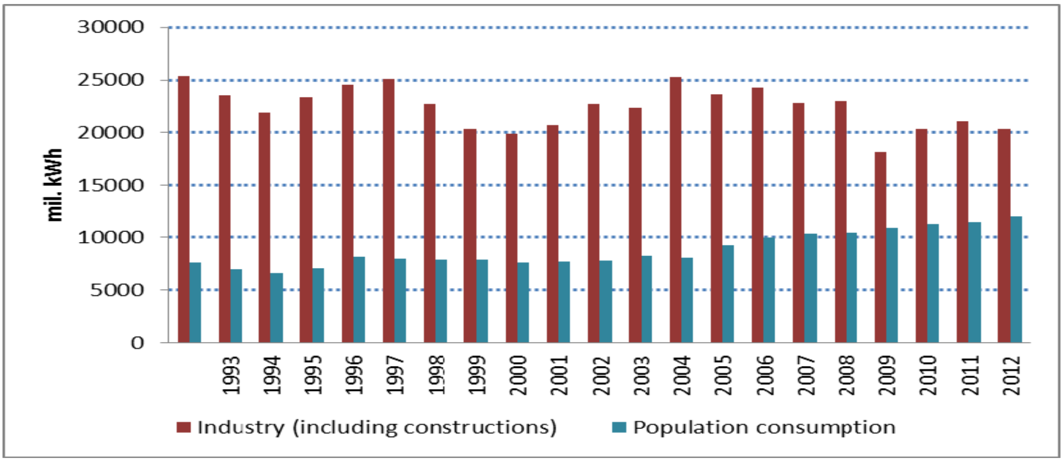

Figure 1. Energy consumption for industry and population
(Source: INS, 2014)

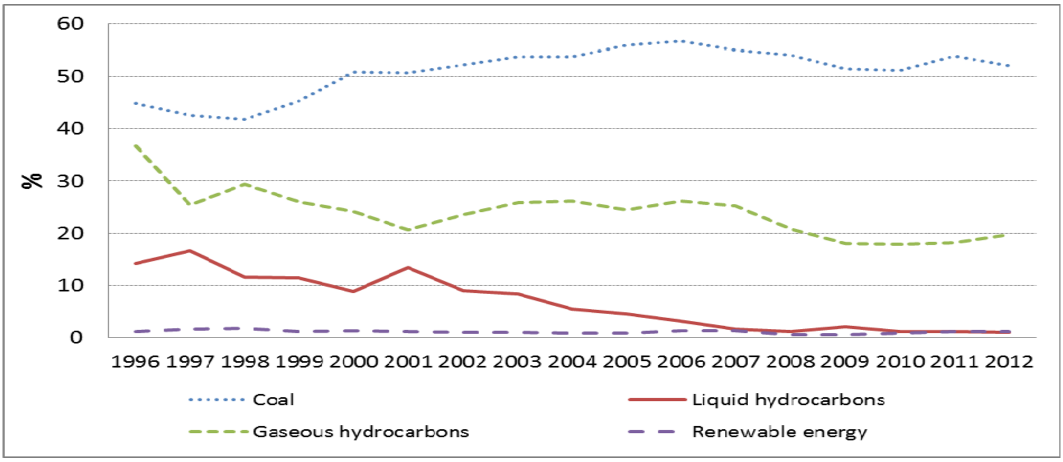

Figure 2. The structure of the thermo-energy production in Romania by fuel
(Source: INS, 2014)

At national level, the degree of energy autonomy varies depending on the raw materials into use (for e.g. national resources of natural gas, oil and coal - especially lignite – can provide Romania's needed quantities for decades), and overall, one can assess that the country's dependence on foreign energy sources is lower than the EU average (in 2011, 21.34% vs. 53.83%) (EUROSTAT, 2013). The relatively low degree of dependence is increasing the resilience of Romanian energy system. Nevertheless, although Romania has 5% of the EU's oil reserves, and, together with Poland and Ukraine, the largest gas reserves, the imports of gas are significant, representing about 17% (99% from Russia) while the imported oil has a higher share - 66% (IEA, 2012).

Energy vulnerability index (I_{ve}) is based on regional energy consumption by households (including private transport), on estimated energy consumption by freight transport, industry, services and agriculture, national industry coal and national energy import dependency. According, the national average value of 41.8 for I_{ve}, Romanian regions have a relatively contrasting situation, some below the average value – North Eastern Region (39) and Bucharest - Ilfov (37), other above the average with a maximum in Southern Region (45). This indicates, once again, deeper vulnerability of North Eastern Region in terms in energy area (European Commission, 2008).

The energy system in North East and South East Regions

In the last 25 years, the economic and industrial transition has shown, on the one hand, the spatial differentiation and the concentration of big polluters particularly in certain regions (e.g. South West or South), while others confront massive industrial decline (North-East) and, on the other hand, the progressive appearance of high-tech industries and smaller but more efficient industrial units in all regions.

In terms of regional structure of electricity production units, their distribution is determined by the availability of energy resources in those areas. South East Region is favoured by the presence of the sole nuclear plants in Romania, and therefore counts for about 21% of the total energy installed capacity, while the North East Region has only 6.5% as it is forced to reduce coal and oil capacities and focus on hydropower and alternative sources. Both regions taken into account still retain, though in unequal proportions, an oversized and inefficient processing industry, fuelled by the energy sector comprising large polluting power plants (figure 3).

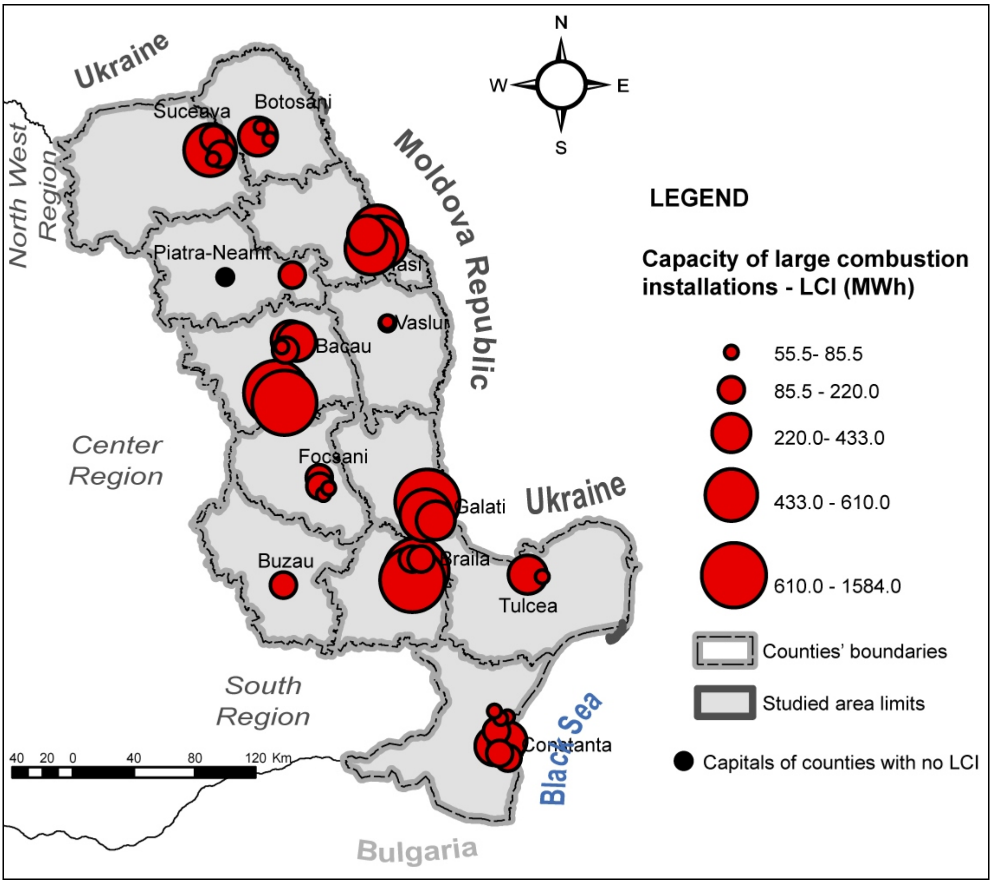

Figure 3. Installed capacities of large combustion plants from Eastern Romania (>50 MW)
(Source: EEA, 2014)

The existing power plants mainly operate on natural gas (Amurco Bacău and the municipal thermoelectric power plants from Iași, Constanța and Tulcea), coal and natural gas (municipal thermoelectric plants from Bacau and Iasi- Holboca), coal (municipal thermoelectric power plants from Suceava, Bacău, Comănești), liquid fuels and natural gas (municipal thermoelectric power plants from Brăila- Chișcani, Palas Constanța and Năvodari).

An urgent measure to be taken is to upgrade power plants in close correlation with the need to comply with European legislation or to close the old inefficient ones. According to Directive 2001/80/EC aiming for limiting emissions of acidifying compounds, dust and ozone precursors, it is necessary to modernize power system components by installing gas desulphurization units using low NO_x emission burners, filters for the upgraded large combustion plants etc. Regarding the emissions from thermoelectric plants built between 1987 and 2002, the limits are less stringent, but, for the previous ones, the time permitted to function before rehabilitation is 20,000 hours, which is worrisome as more than half of the Romanian power plants are over 30 years old and 20% are aged between 20 and 30 years. Having in view these provisions, some power plants in the east were closed (units in Brăila, Vrancea or Onești), others have stopped some of their capabilities (Suceava, Constanța) while others have worked for a limited number of hours (Borzeşti) or have been completely modernised by accessing EU funds (Botoșani).

The alternative of renewable energy

Renewable energy sources in Romania have an average potential at European level, standing out especially in terms of hydropower (Carpathian and Subcarpathian) and wind energy (Carpathian regions). In solar energy, the potential is higher than the European average in all Romanian regions which give the country the opportunity to become a major player in Europe along with Mediterranean countries. The renewable energy capacities had a highly ascendant dynamic, until recently, also because of a very attractive legislation (green certificates at very low prices, an opportunity that was finally limited), which led to an exponential increase in foreign investments in this area. Analysing the regional electricity generating units in the two regions considered (table 1), one can observe the absolute dominance of the South East region (second in Romania after the South Region, which has 38% of the national total), which turns to account a diversified potential of renewable energy, attractive to foreign investors, but also a certain hydropower potential (especially micro-hydro plants) in North East Region.

Table 1. The regional structure (NE and SE regions) of the energy systems installed in capacities in 2013 (Data source: Bădileanu et al., 2014 and own calculations)

Region	Energy resource	Installed capacity in 2013 (MW)	Share of the total country (2013)	Employees (no)
North-East	Coal	240	3,84	1162
	Hydrocarbons	358,6	7,44	30
	Hydro	671,9	10,8	563
	Wind	66	3,22	6
	Total	1336,5	6,54	1761
South-East	Hydrocarbons	912	20,65	1042
	Nuclear	1413	100	2136
	Wind	1933,4	94,40	174
	Solar	7,7	8,56	2
	Total	4266,1	20,90	3354

The small hydropower plants can be a source of basic power supply of isolated rural areas and consumers (high altitude cottages, weather stations, etc.). In the studied area, most of these facilities were built in the Carpathian areas corresponding to Suceava and Neamț counties (1.80% of the total national installed capacity). Biomass is the main source of fuel in rural areas, being used for domestic heating and cooking. It includes mainly agricultural and forestry biomass, but also waste from industrial exploitation of timber. Although it has a significant potential, modern biomass energy recovery is still at an early stage, while the largest units are installed in Neamț County (15.8 MW, representing 25% of total installed capacity at national level). Photovoltaic energy units are installed in extra-Carpathian areas with high insolation from southern and eastern Romanian Plain and Dobrogea (8.38% of total national capacity). Although solar energy is free, the technologies needed to catch it and convert it into electricity is expensive, so it took an attractive legislation (6 green certificates for each MWh) to attract foreign investors. Many photovoltaic parks were installed and others are in the design phase, but, nevertheless, investments in solar energy (about 70 million euro in 2012) are more modest than those of the wind sector (3 billion euro in 2012) (Colesca, 2013). Wind power not only has great potential in the Eastern part of Romania, but is also well capitalized, representing, in fact, the basis of renewable energy in Romania, with the largest investments (Wenisch, 2003).

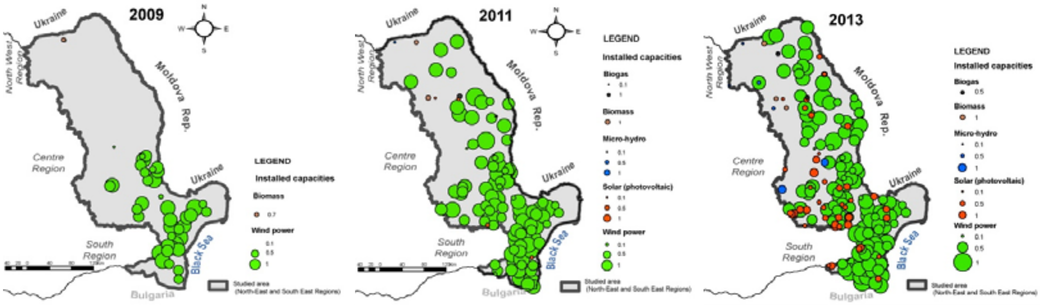

Figure 4. The dynamics of investments in renewable energy in Eastern Romania
(Source: ANRE, 2014)

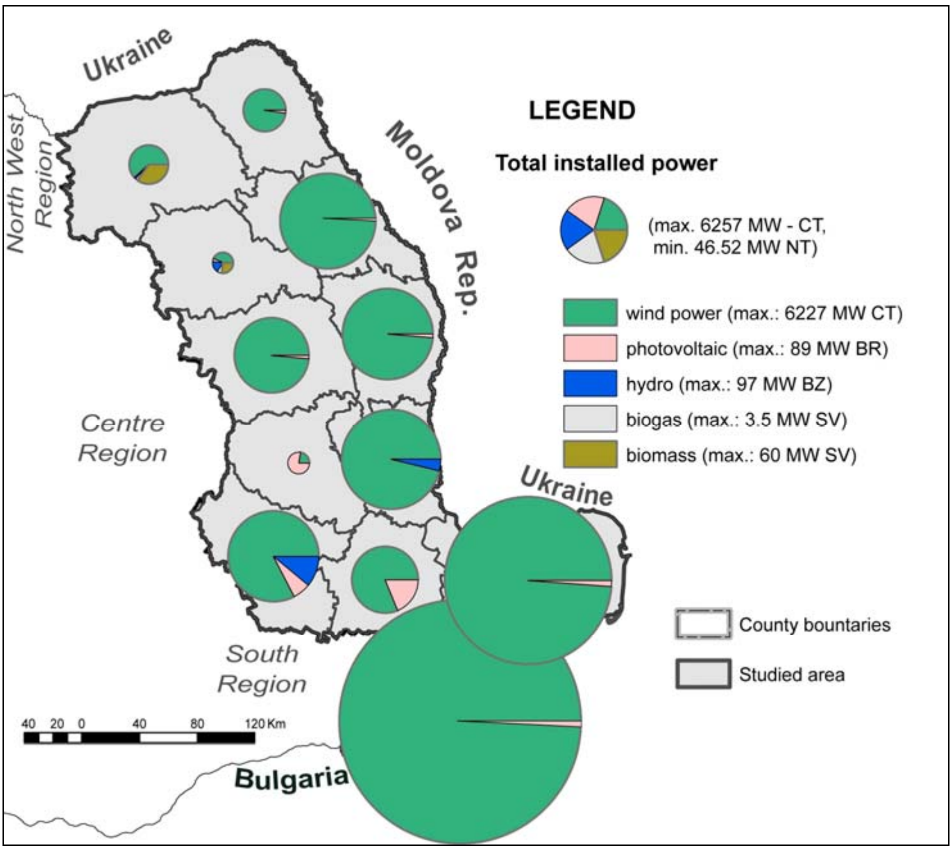

Figure 5. The share of different renewable energy capacities in Eastern Romania
(Source: ANRE, 2014)

The use of wind energy has a long tradition in Moldova and Dobrogea, since the nineteenth century, when it was used for small scale cereal milling and for pumping water. Regarding the modern wind power plants put into operation, North East Region has about 3% of the installed capacity, while Dobrogea holds almost 43% of the plants currently producing electricity from wind power.

There is a nearly continuous area of large investments this type of energy in the south – eastern part of the country, as many wind turbines were installed in the last 6-7 years (Constanța county holds a total of 5400 MW installed wind power, 37% of Romanian capacity, Tulcea - 2500 MW, while Galaţi - 1,000 MW).

CONCLUSION AND PERSPECTIVES

In terms of adaptation cycles stated by resilience theories, national energy system is currently under *reorganization phase* expressed by resizing or closing of conventional polluting units and high investments in energy sources diversification. However, there is the possibility for future failures, since electricity consumption increases, while the existing tensions in the European energy market, in terms of constant and reliable supply for classic fuels (oil and gas especially), do not seem to decrease in the years to come. In Eastern Romania there are conditions which ensure the diversity of energy sources, in particular wind and photovoltaics for plateau and plain areas, biomass, biogas and small hydropower for the Carpathian and Subcarpathian area.

The analysis of the resilience capacity of national energy system can be extremely important in determining economic development policy objectives, in order to make effective decisions about the allocation of funds, about financial and technical assistance or about assigning a special status to the most vulnerable regions. It is also important for the competent authorities to understand the requirements of common European energy policy in order to promote necessary measures for developing and strengthening the adaptive capacity of large electricity generating units to support development and investment opportunities in the national energy sector. In the future, energy security and resilience should be designed in terms of decentralization and local use of renewable resources to ensure stability and energy autonomy for both production and distribution services.

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