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REVIEW OF ENERGY INVESTMENTS FOR STRENGTHENING RESILIENCE IN ENERGY SYSTEM

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Abstract. The provoked shock in the energy system came into a moment in which climate impact is more and more visible and took several types. The rise of prices has determined economic incentives for increasing the offer and for choosing the alternative or more efficient ways to satisfy the demands. The shocks due to energetic security have created strong incentives for politic decisional factors for reducing the dependences and vulnerabilities, but in the same time for a lot of developing countries, the financial resources are depleted. The last years were a period of extreme perturbation for energy sector.

1. Introduction

EU governments and decisional factors are still discussed how best to contain the dramatic impact of high energy prices on households, industry and the whole economy, when winter has come [1],[2]. In the same time the European Commission has indicated its intention to formulate proposals for longer-term adjustments to Europe's current electricity market design, the importance of distinguishing between short-term crisis management and long-term market reform initiatives.

It has to take into account the capital flows in energy sector and the way in which investors can evaluate the risks and the opportunities in all supplying domains with combustible and electrical energy, critic minerals, efficiency, research and also finance in energy domain.

The characteristics of climate crisis solutions are:

- the current policies which consolidate incentives for green energy costs;
- the energy security perspectives;
- general pressure above costs and inflation;
- the major increase of incomes to traditional suppliers due to high prices of fuels;
- growing expectations that the investments will be aligned to climate crisis solutions.

The recovery due to Covid-19 pandemic and the answer to global energy crisis have given a significant boost for investments in clean energy. As well, it is essential to distinguish between pure market project elements and complementary mechanisms aiming to address remaining market failures [2],[3].

The future investments have to shape a European electricity market that is resilient to shocks and supports the accelerated implementation of renewables over the next three decades.

2. Review of energy investments

The annual investments in clean energy have risen faster than investments in fossil fuel between 2021 and estimated for 2023 (24% for green energy and 15% for fossil fuel). This analyse emphasises the way in which the intense volatility period on fossil fuel market has accelerated the impulse behind technological investments in clean energy caused by the Russian invasion in Ukraine. Wartime interventions should be proportionate, short-term and reversible, while sensible long-term reform proposals that support the energy transition may not help with the current crisis.

It is estimated that were invested about 2800 billion of dollars in energy in 2023. More than, about 1700 billion of dollars were invested in clean energy, included the renewable resources, nuclear, energy storage systems, the combustible with low emissions, increasing efficiency and final energy using from renewable sources and electrification. Only 1000 billion of dollars were allocated for fossil fuel and electrical energy supply (15% for hard coal and lignite and 85% for petroleum and gas). For every dollar spent of fossil fuel about 1,7 dollars are spent for green energy. Five years ago, the percentage was 1:1. During the global energy crisis, the investments in renewable energy, grids and energy storage systems have been accelerated

but the capital costs for energy generated from fossil fuel were increased (fig. 1).

The investments in energy sector have increased with 12% in 2022, and for the first time overtook about 1000 billion of dollars and increasing was about 1200 billion of dollars in 2023.

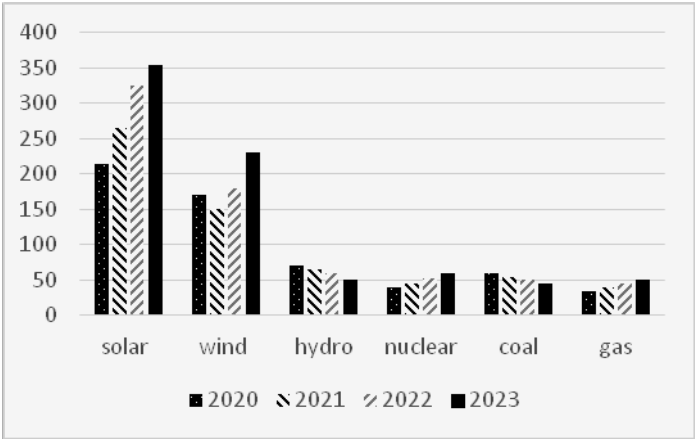

Fig. 1. Electric energy global annual investment (billions of dollars) for different technologies

The abundant incomes and also the increased prices have determined the growing investments in fossil combustibles but of course, the costs are limited by the concerning of costs and demands on long terms. 2022 was an extraordinary year for carburant suppliers and dealers. The Russian invasion in Ukraine has determined growth of gas prices over the record levels all around the world, but the petroleum prices have returned of 2010 level. The net incomes have increased from fossil fuel sales, as the world petroleum and gas industry gained about 4000 billion of dollars.

The increased prices have stimulated a growth of investments in fossil combustible. Taking into account some ratings, the investments in new supply sources based on fossil combustible grow up with 6% till 950 billion of dollars [4],[5].

The world energy crisis has stimulated the costs for efficiency, electrification and final energy from renewable sources with 16% in 2022. Emerging market economies recorded a growth of investments

about 19%, China being the only one which recorded a decreasing of investments in energy efficiency due to continuous jam of Covid-19 and real estate crisis. Also, the growth of investments was made for heat pump installations. The investments in electrification of transport systems were about 60% in 2020 and the electric vehicles sales reached record levels more than ten million of units.

The costs of energy research and developing grow with 10% in 2022 reaching about 44 billion of dollars and 80% of them for green energy domain. It is a trend which push the innovation in spite of macroeconomic doubts (as Net Zero industry Act and Industrial Plan Green Deal). Also, in European Union, Innovation Fund has given a direct financing of 1,8 billion euros for seventeen projects for batteries, Hydrogen, dollar energy and wind energy. As a response of actual energy crisis, next budget was doubled at 3 billion of euros.

The financial community has an important role in massive growth of outgoings for clean energy, necessary for fulfilling the climate objectives and for relocation of capital budget without of fossil fuel.

The promotion of sustainable financing is a strong key due to the high number of financial institutes which align the financing to net zero scenarios. The global value of the fund`s assets decreased in 2022 but the sustainable funds proved more resistance and recovered at the beginning of 2023 despite of some exits from huge funds ESG (Environmental, Social and Governance).

3. Strengthening resilience in energy system

The extreme climate phenomena are increasing as frequency as the extend challenging damages physical assets to gas transport infrastructure or electric energy infrastructure. The extreme weather conditions affect the renewable discontinuous disponible as wind or solar energy as the energy demand volatility.

The European electrical energy and gases systems also became interdependence due to reaching the net zero objectives for achieving a just transition and a carbon-neutral economy by 2050 requires unprecedented joint efforts, which determines efficiencies in the same time with vulnerabilities resulting from introduced distributed systems.

A reliable and resilience has appeared as a new paradigm applying across many energies sector and infrastructures. Resilience can be defined as the ability of infrastructures to overcome ex-

treme events with minimum disruptions, including duration of the restoration phase system.

Resilience is the essence for European energy transition, which has to resist, to adapt and to fast return when is affected by the climate hazards. So, it is essential to search an answer for how can the European Union settlements and legislations to support and to create incentives for a resistant infrastructure [4].

The Report "Strengthening resilience in European energy system" emphasizes the consequences of hazards due to climate changes and how the extreme climatic events can increase both in terms of frequency and scale, causing serious damage to physical assets such as gas and electricity transport infrastructure. Different ways of bringing the required investments, costs will, however, almost certainly increase the quality and reliability of energy supply Europe accustomed to is to be maintained [3,4,5].

The divergent approaches of national regulatory show there is not a clarity on methodologies regulators use to monitor operators' resilience assessment and investments**,** and also in terms of guidance as to the prioritisation of investments to consolidate the resilience.

It has to promote a more comprehensive and more integrated understanding. The European energy regulatory approaches in specific way some resilience features as: energy grid planning; operational system manage; technical performance. This is a good start, but resilience has to be more integrated and defined as an evaluation and mandatory demand, determining strong incentives for investments for limiting the over costs in case of major breakdown. So, it is necessary a larger evaluation domain (as flexibility) and a long-term perspective.

An essential role for network operators remains to identify and evaluate the risks which are the base of investment decisions and plans.

Moreover planning, preparation for urgent situations, restauration and technical performance, the resilience building must be better integrated through cooperation markets level, plus a strong interaction between grid operators and other operators (flexibility suppliers, auxiliar and equilibrium services) which contribute to resilience.

The projects of Intergovernmental Panel on Climate Change should show an extra growth of frequency of hazard while Europe made faces with higher incidence of climate hazard in the last decades (fig. 2).

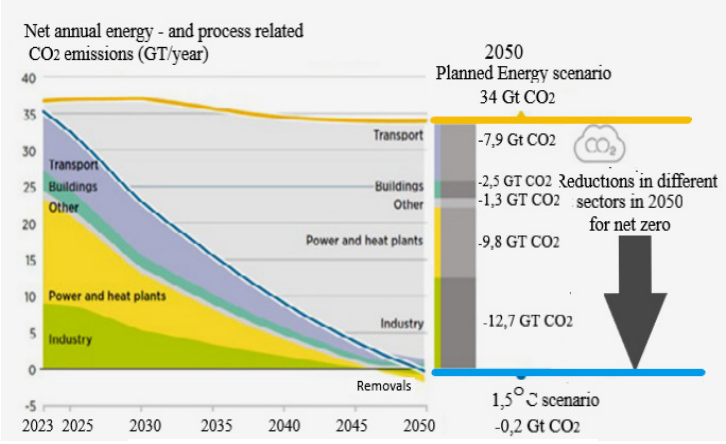

Fig. 2. Estimated trends for CO_2 Emissions for

1,5°C Scenario 2023-2050, Source: www.irena.org

The impact will be in dependence with the success of climate reduction significative efforts for the global warming to be limited at 1,5°C. The higher levels of warming would have a stronger impact. So, the extreme temperatures phenomena frequency, which can determine a huge risk of forest fire and can affect the underground electrical lines, will increase probably with 50% in comparation with the actual level and more than fourth times without warming; the abundance of rains on shores will increase with 15% and could be probable with 50% more than present warming level of 1°C.

Europe has established the ambitious goal to became neutral from climate point of view till 2050. An intermediary goal is to reduce with 55% the emissions till 2030 in comparation with 1990. European Commission has proposed that the energy percentage of renewable resources to be double into decade from 20% to 40% in 2030 as a component of this goal.

The resilience strengthens and ensuring have necessary of structural steps. The investments are urgent and vital for realise the energy sector resilience as well as functional methods adaptation to "new normality" of extreme events. This reality is relevant in

the climate changes as well as the wartime, energy crisis and the growth of bound of gas and electricity sectors. Due to the increased nature of bounding between the gas and electricity sectors, new gas and electricity resilience metrics may be needed that reflect increasing inter-dependence and feedback between the two sectors and how one sector can support resilience of the other sector.

The resilience of gas systems and electrical systems can be affected by a several factors in the climate changes context.[4] The natural gases system resilience is in dependence with:

- vulnerability to extreme weather events (as suddenly drop air temperature resulting the increase in demand for space heating, hurricane disrupting offshore gas production facilities, etc.) that can increase demand and disrupt supply and delivery infrastructure system;
- the dependence on a limited number of suppliers, transportation routes and storage facilities should increase the risk of supply disruptions due to war and geopolitical situations;
- leakage of methane during production and transportation, which can negatively impact the environment (for example explosion of the Nord Stream offshore gas pipeline).

The electricity system resilience is in dependence with [5],[6]:

- vulnerability to extreme weather events (as hurricanes, heat waves) that can impact power generation, transmission and distribution networks;
- dependence on centralised generation and transmission infrastructure, which can be vulnerable to cascade failure and cause widespread interruptions;
- increasing integration of renewable energy sources, such as wind and solar, which can be distributed and weather-dependent so require additional investments in grid infrastructure and storage solutions to increase resilience.

It is considered that in 2050 Romania will allocate around 10TWh with purpose of suppling the electrolysis for the production of hydrogen; the construction of electrolysis about 1500MW will be required as a production of about 0,2Mt H_2/year. Making a comparation between emissions the hydrogen produced by electrolysis of water causes the lowest emissions as: solar 1,0kg $CO_{2\ equivalent}$/kg H_2; wind 0,5kg $CO_{2equivalent}$/kg H_2; nuclear 0,6 $CO_{2equivalent}$/kg H_2 and 0,115g nuclear waste; hydro 0,3 $CO_{2\ equivalent}$/kg H_2.

The energy efficiency has to preserve the same level of operating, safety and performances for energetical system and some possible measurements could be applied to diminish the energy crisis in Romania [6,7,8]:

- the resources allocation by the central and local authorities for professionalisation and increase of the skills of the workers in the energy field and for combating climate change in the context where investments in these sectors are significant;
- updating by training institutions, including those of higher education, of curricula for energy and environment with an emphasis on cooperation and interdisciplinarity;
- significantly more consistent funding for fundamental and applied scientific research for energy efficiency technologies, renewable sources and low emission mobility;
- partnerships between professional associations with tradition and professional associations with an energy profile for information sessions in the field of energy transition towards decarbonize [9], [10].

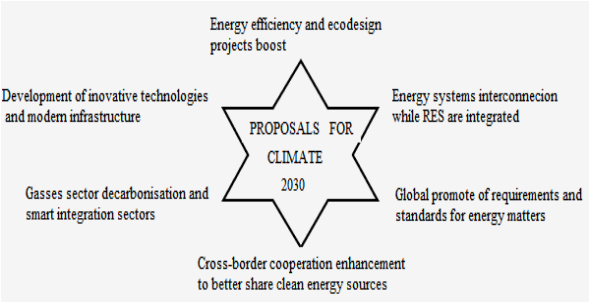

Fig. 3. The Romania climate objectives

In the last years, almost of 3000MW were put out of operating another 1475MW till 2025 and 2300 MW will put out of operating till 2030 in Romania.

It has to take account the bound between geography and existed resources of every state or region isolated. Poland and Germany have coal, Denmark, Finland and Romania have access and gas resources off-shore, states from the Carpathian and the Alps have hydroelectric potential as well as the states from North Sea have wind potential or the states from south of Europe have solar potential, so, not all states could have the same energetical mix.

Romania is ready to meet tight deadlines for European funding, increasing energy independence from Russia, decrease the effects of the European energy crisis and decarbonize its economy. In Arad in Romania's west, will be installed the largest photovoltaic plant in Europe as it joined a 1.04 GW project developed by Monsson [6,9,10].

Conclusions

The existing structure of the European market has produced an integrated, or "coupled," European market where production and distribution are handled by a range of different companies competing for customers. The energy system has to responsible rethink for assuring the energy independence. The renewable sources alone will not be able to ensure a constant and sufficient level of electricity supply and a flexible balance with classical sources will be ensured, avoiding their elimination before securing a replacement.

In the context of the drastic reduction of oil and natural gas reserved, with consequences on the prices of petroleum production and delays in finding solutions for storage electricity, obtained from renewable sources or the emergence of geopolitical events with major economic implications for national without immediate solutions to equilibrate the balance, coal remains a bridge in the medium term, during which adopting the problems of adapting the new types of resources must be gradually resolved.

While some of the reform proposals for the power market make sense, these won't address the scope of the energy crisis in a timely manner. But speeding up some of them would advance their advantages. Such adjustments must be considered in the medium term in light of the 2030 and 2050 climate goals.

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