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Content

Editorial

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At the 2021 Brussels Summit, Allies once again reaffirmed the importance of energy in their common security.

In the declaration, they underlined the significance of a "stable and reliable energy supply, the diversification of routes, suppliers, and energy resources," highlighted the need to "support national authorities in protecting critical infrastructure" and stressed the necessity to "ensure reliable energy supplies to our military forces." And these are but a few, brief extracts from the full text.

If one were to comb through the full declaration, one would quickly realise that Allies have a very tall order to fill. They have to simultaneously strengthen their energy supply lines, keep an eye on their critical energy infrastructure and improve military energy efficiency, all while trying to do their fair share in tackling climate change.

Here at the NATO Energy Security Centre of Excellence we are at the forefront of supporting Allied efforts to the best of our abilities. Therefore, in this issue of Energy Highlights, we will focus on three starkly different, but equally important energy-related challenges that NATO members and their allies face. This, we hope, will help shed some light on the complexity of the task at hand.

In the first article, Mr. Lukas Trakimavičius examines the future role small modular nuclear reactors (SMRs) could play in the military. He argues that SMR's could not only contribute to military operations by increasing energy assurance, help save lives by reducing the need for fuel resupply convoys, but could also help cut greenhouse gas emissions by providing a low-carbon source of energy. Yet, Mr. Trakimavičius also warns that currently there are still too many questions surrounding the potential risks and the future need of military SMRs. Therefore, he concludes, that only if these issues are properly dealt with, it would make sense to consider military SMRs more seriously.

In the second article, Dr. Oleksandr Sukhodolia and Mr. Vytautas Butrimas identify and analyse the success of hybrid warfare tools used by Russia in the Ukrainian energy sector between 2014 and 2017. More specifically, it focuses on the different types of aggression that were carried out against critical energy infrastructure, which include, but are not limited to, cyber-attacks and the physical destruction of equipment. The authors also examine the implications of these incidents for Ukraine and highlight the broader lessons that could be drawn from them.

In the final article, Mr. Krzysztof Kociuba and Mr. Gerard M. Acosta assess Poland's energy security outlook and explain the country's energy diplomacy policy. By highlighting how Poland has managed to leverage its national resources and its economic potential, the authors also demonstrate how Warsaw has succeeded in strengthening its energy security and reducing its acute reliance on energy supplies from Russia.

These three very different articles serve as an important reminder that energy security is not this single, monolithic subject, which only deals with pipeline politics or oil and gas monopolies. Instead, energy security should be viewed as a large and multifaceted issue, which involves a myriad of actors and requires a panoply of measures, innovations, tools and legislations.

In short, energy security is exactly as important and as complex as described in the latest Brussels declaration.

Is small really beautiful?

The future role of small modular nuclear reactors (SMRs) in the military

by **Mr. Lukas Trakimavičius**

"Amateurs talk strategy, professionals talk logistics" is a well-worn adage, which over the years was attributed to numerous famed individuals, ranging from Napoleon Bonaparte to Omar Bradley, General of the United States Army during World War II. Regardless who the real author was, this adage contains an obvious kernel of truth. Modern armies cannot move, fight or perform any of its duties without massively complicated supply lines and the tireless work of logisticians. Perhaps even more importantly, none of the above would be possible without a constant supply of energy, whether in the form of countless canisters of petroleum or a steady stream of electricity. In other words, energy is the undisputed lifeblood of the military.

For most of the 20th century, energy security for the military meant having an unfettered and abundant access to fossil fuels. Oil and its products would power the engines of ships, planes and vehicles, and, in times of conflict, it would generate electricity for bases and military facilities alike. However, in recent decades there has been a slow, but steady shift from a fossil fuel-dominated perspective of energy security. Owing largely to the looming threat of climate change and the shifting tides of politics, most Western militaries became increasingly conscious about the environmental toll of burning fossil fuels and consequently got involved in efforts to reduce greenhouse gas (GHG) emissions. On a more practical level, wars in Afghanistan and in Iraq taught Western militaries bitter lessons about the costs, both financial and human, of long supply lines, which extend through hostile and unforgiving terrain.

Under these circumstances, it is unsurprising that Western militaries started to look for ways to strengthen their operational capabilities by embracing clean and innovative energy solutions.

by **Mr. Lukas Trakimavičius**

Mr. Lukas Trakimavičius works at the Research and Lessons Learned Division of the NATO Energy Security Centre of Excellence. Previously, he worked at the Economic Security Policy Division of the Lithuanian Ministry of Foreign Affairs. He also held several positions at NATO, where he focused on energy security, arms control, disarmament and non-proliferation.

This is where small modular nuclear reactors (SMRs) come into play.

Proponents have long argued that by adopting SMRs militaries could limit GHG emissions and reduce their dependence on fossil fuels, long supply lines, and civilian energy grids. The civilian sector would also benefit from it, because it could take advantage of an innovative technology without having to shoulder all of the developmental risks and expenses.[1] Others, however, disagreed and claimed that SMRs made very little sense for the military. By pointing out the dubious economic rationale of these projects, the unaddressed issue of spent fuel, the threat of nuclear proliferation and the risk of accidents, they argued that SMRs would likely do more harm than good.[2]

Yet, as it usually is the case, the truth lies somewhere in the middle. Like most technology, SMRs do not easily lend themselves to generalization and by some accounts their benefits indeed outweigh the cons. At times, the opposite is also true.

In turn, this research paper will explore the history and development of SMRs, discuss their technological features and examine the utility of SMRs through a number of different angles, all while trying to address the question of whether SMRs could be useful to Western militaries.[i]

HISTORY OF SMALL NUCLEAR REACTORS IN THE MILITARY

It is a common misconception that smaller-than-usual nuclear reactors — the predecessors of modern day SMRs — are based on fundamentally new technology. In fact, this is a technology that is nearly 70 years old and whose origins can be traced all the way back to the early days of the Cold War.

In the United States, the earliest research and development on multiple types of small nuclear reactors began in the immediate aftermath of World War II. From 1946 to 1961, the US Air Force spent around €1 billion trying to build a reactor to power long-range bombers, though to little avail.[3] The US Navy had better success with harnessing nuclear energy and, in 1954, it built the *USS Nautilus*, the world's first nuclear-powered submarine.[4] Six years later, the US Navy launched the word's first nuclear-powered aircraft carrier, the *USS Enterprise*.[5] Meanwhile, the US Army also ran a nuclear energy program from 1954 to 1979. Over two decades, it built and operated eight small power reactors, which mostly were deployed at remote military bases.[6] This program was moderately successful, but it was gradually abandoned due to the questionable cost-effectiveness of the technology and the post-Vietnam war spending cuts.[7]

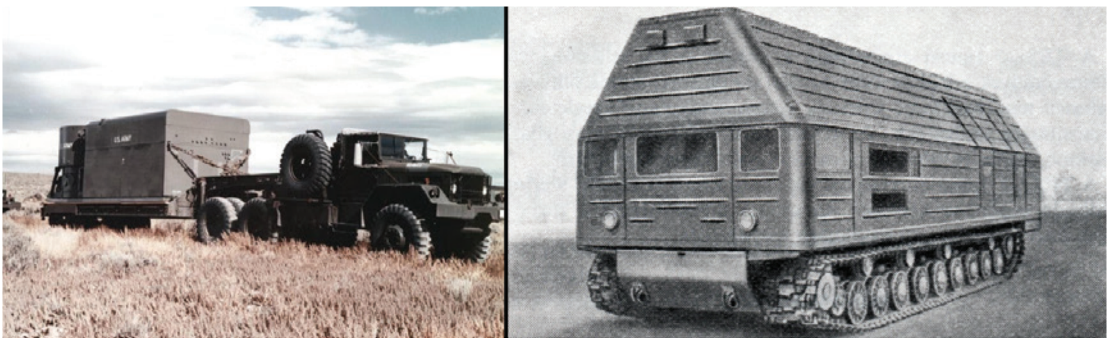

Figure 1. Early experimental portable small nuclear reactors. ML-1, United States; TES-3, Soviet Union (left to right). (Credit: Bellona.org)

[i] This article does not intend to provide a comprehensive assessment of the benefits and challenges associated with developing and deploying SMRs at a strategic, operational or a tactical level. There are existing studies and that have already accomplished this task with great success. Nor is the goal of this paper to provide a detailed technical analysis of the SMR market or a history of nuclear energy research. Rather, its goal is to provide a brief introduction of SMRs and a broad policy-level overview of the pros and cons of using SMRs in a military setting.

The Soviet Union, too, was busy maintaining an active small nuclear reactor program. In 1958, the Soviet Navy launched their own nuclear-powered submarine — the *K-3 Leninsky Komsomol*.[8] Three years later, the Soviets succeeded in building a mobile small nuclear reactor, named TES-3, which was carried around on a modified chassis of a T-10 tank.[9] At around the same time, the Soviet Air Force has also developed a nuclear-powered aircraft. The retrofitted Tupolev Tu-95LAL bomber managed to complete some 40 research flights, but the program was scrapped in 1969.[10] Lastly, in 1988, the Soviet Navy started working on the *Ulyanovsk* — the country's first nuclear-powered aircraft carrier — but due to the collapse of the USSR, the project was scrapped in 1991.[ii]

During the Cold War, only the US and the USSR seriously entertained the thought of using small land-based nuclear reactors for military purposes.[12] Due to a number of reasons, including cost and utility, other nuclear powers had fairly little interest in small nuclear reactors beyond the realms of naval engineering and scientific research.

PUTTING THE M IN THE SMR

While small nuclear reactors are hardly a novelty, the same cannot be said about SMRs. They are quite similar to small nuclear reactors in terms of size, power output and the basic technology, but differ in one very key respect: modularity. Within this context, the term "modular" means that, unlike conventional nuclear reactors, both small and large, SMRs were manufactured in a factory and could be transported by truck, rail or plane directly to the plant site. Even if most nuclear reactors, both new and old, rely extensively on factory-built components, a good deal of field work is still necessary to assemble these components into an operational nuclear power plant (NPP). In contrast to small and large nuclear reactors, SMRs have a much more streamlined design, enhanced safety features and their modules can be added incrementally to meet changing energy demand. In other words, SMRs are thought to be ready to "plug and play" upon arrival, reducing both capital costs and construction times.

In terms of power output, SMRs are defined by the International Atomic Energy Agency (IAEA) as reactors that are capable to generate up to 300 MWe per module. This contrasts with medium-sized nuclear reactors, which can produce between 300 MWe and 700 MWe, and large nuclear reactors whose maximum power output is 1000 MWe or greater. SMRs can also be subdivided into different categories. Some institutions and energy companies employ a wide variety of terms, including "micro modular reactors" (MMRs) and "very small modular nuclear reactors" (vSMRs) to describe SMRs that have the capacity to generate up to 10-25 MWe per module.

However, considering that the terms "MMRs", "vSMRs" and "SMRs" are frequently used almost interchangeably and that, conceptually speaking, they refer to relatively similar objects (though the size and the power output of the reactors vary), for the sake of convenience, mostly the broader term "SMRs" will be used throughout this research paper.

From a reactor design perspective, the majority of today's SMRs can be broadly divided into two categories: those whose mature designs use water for cooling purposes, and those whose advanced designs do not. The latter's designs may employ a diverse range of materials such as helium, sodium, lead, molten salt and others. As things stand now, light-water reactors and gas-cooled reactors have by far the greatest technological maturity (based on the number of reactor-years of experience) and, therefore, they are best suited for near-term deployment.[13] Other designs, such as liquid-metal cooled reactors, have great potential for longer term development and deployment, but they need additional work to achieve viability in the marketplace.

Currently, there are around 70 SMR designs and concepts globally. The bulk of the research is concentrated in countries such as Canada, China, Japan, Russia, the US and South Korea.[14] Most of these SMRs are in rather early stages of development, though some are claimed as being

[ii] The United Kingdom launched its first nuclear-powered submarine, the HMS Dreadnought, in 1960. Eleven years later, France commissioned its own nuclear-powered submarine, the Redoutable.

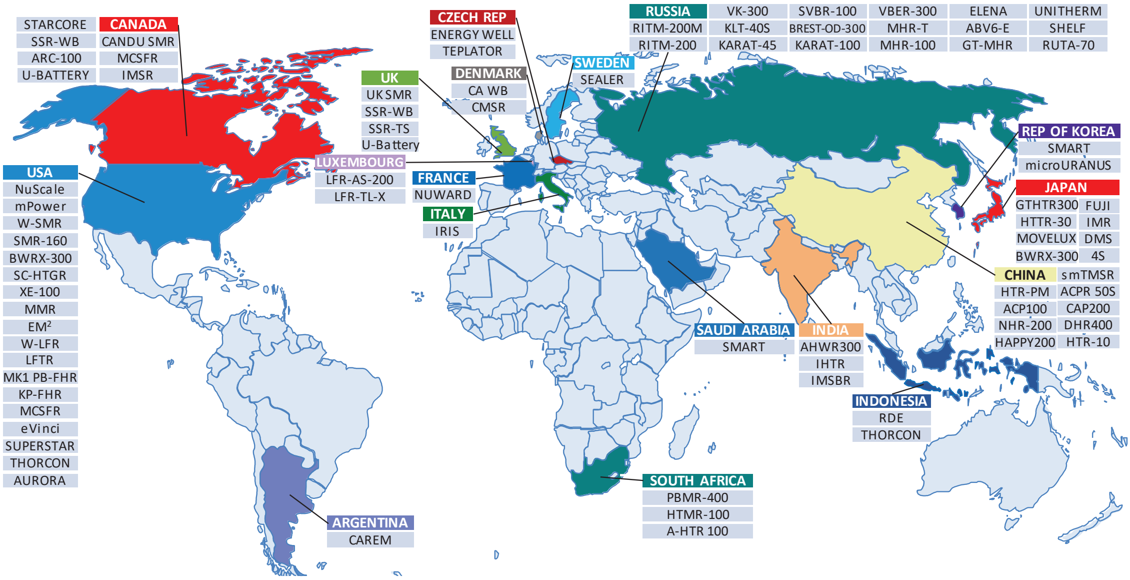

Figure 2. Global map of SMR technology development (Credit: IAEA)

mature enough to be near-term deployable. For instance, the Korea Atomic Energy Research Institute is eying to launch its first commercial 100 MWe SMR in Saudi Arabia in 2028.[15] Meanwhile, NuScale Power, a US-based company, is hoping to get its first commercial 60 MWe SMR module up and running in Idaho by 2029.[16]

There are also other promising designs from companies such as GE Hitachi Nuclear Energy, Terrestrial Energy and OKBM Afrikantov (a subsidiary of ROSATOM), just to name a few, whose commercial land-based SMRs might be built in the coming decade. Though it still remains to be seen if any of these companies will succeed in actually building their SMRs, or if they will fail like some of their predecessors.[III]

MILITARY INTEREST IN SMRS

In light of the changing politics, technological advances and operational requirements, recent years have been marked by an unprecedented surge of interest in military applications of SMRs.

The Russian military was among the first to make it clear that it wants to have SMRs at its disposal. Back in 2015, Russia's Ministry of Defense said that it was planning to develop up to 30 SMRs in its Arctic region. These reactors would provide electricity to remote bases and military facilities, which are currently under development as part of Russia's broader Arctic militarization plan. The SMRs would be small enough, so that they could be shipped by truck, on a sledge or even carried by heavy cargo helicopter, such as the Mi-26.[17]

More recently, in 2019, Russia launched its first floating NPP, the *Akademik Lomonosov*.[18] Named after the 18th-century Russian scientist, the 144 meters long and 30 meters wide vessel houses two 35 MWe modular nuclear reactors. According to its designers, *Lomonosov* is a "working prototype" for a future fleet of floating NPPs and land-based installations based on SMRs technology.[19] To date, Russia has not made it explicit that Lomonosov will be actively used by the country's military and claimed that its SMRs

[III] In recent years a number of high-profile energy companies have abandoned their plans to develop SMRs. Westinghouse — a US energy company — worked on a mature SMR design for about a decade before dropping it in 2014. More recently, a mature SMR design by Babcock & Wilcox — another US energy company — was scrapped in 2018, despite €95 million funding from the US government.

would be mostly used to power remote cities or research facilities. Yet, given their versatility, there are few doubts that floating NPPs like *Lomonosov* could eventually be used at military bases along the north coast of Siberia and on remote archipelagoes such as Novaya Zemlya or Franz Josef Land.

China's military, too, has expressed its interest in SMRs. In 2016, reports have surfaced that the Chinese Academy of Sciences' Institute of Nuclear Energy Safety Technology was developing an experimental SMR — dubbed the *hedianbao* — and received partial funding from the People's Liberation Army for the project. According to the researchers, these SMRs would be very small, measuring about 6.1 meters in length and 2.6 meters in height. They could be moved inside a shipping container, generate up to 4 MWe and would be installed on islands of the South China Sea.[20]

In 2019, the state-owned China National Nuclear Corporation (CNNC) also stated that it was interested in developing floating SMRs. According to the CNNC, the first demonstration unit — *the Linglong One* — will have the capacity of 125 MWe and it will be built on the island province of Hainan.[21] The CNNC's public statements suggests that the floating SMRs will be predominantly used to power islets and offshore drilling platforms that may otherwise have little or no access to the onshore grid power supply. However, bearing in mind Beijing's rapid militarization of the South China Sea, and its fierce rivalry with neighboring countries, there is little doubt that the floating SMRs could also be used to strengthen China's military foothold in the region.

The US military has also signaled its interest in SMRs. In 2019, the US Department of Defense (DOD) announced its plans to develop a SMR as part of a program called "Project Pele". According to the DOD, the reactor would be able to generate between 1-5 MWe for over three years without refueling, weigh less than 40 tons and be small enough to be transported by truck and cargo aircraft, such as the C-17 Globemaster. The DOD hopes that it would not take more than 72 hours to assemble the SMR on-site and that it could be disassembled in less than a week. In early 2020, the DOD already issued contracts for three US nuclear energy companies (BWXT, Westinghouse, X-Energy) to start work on a SMR design. It is hoped that, following a two-year engineering competition, a mature SMR design prototype will be selected, and that its outdoor testing could begin in 2024.[22]

To date, there has been little evidence to suggest that with the exception of Russia, China and the US any other countries would be seriously considering to develop and deploy SMRs for their military needs. This is likely the case because only a limited number of countries have enough experience of working with nuclear energy at a sufficiently advanced level. And, even within this slightly narrower list of countries, which possess the industrial capacity and the know-how to develop SMRs, there are even fewer countries, which have the military need or the financial resources for such an endeavor. Therefore, if things stay as they are right now, it is very likely that in the coming years and decades, most of the military-related SMR innovation will take place within this group of three.

Yet, despite the recent surge in popularity, SMRs, and, especially the highly-portable MMRs, remain a fundamentally unproven technology. It might take decades before they could be adopted by the militaries in large numbers, if at all. Considering the time, effort and money that any large-scale military SMR program would require, it is only prudent to review and examine the different factors that could affect their development and deployment.

POLITICAL CONSIDERATIONS

For better or worse, civil nuclear energy is already a controversial topic in itself. Advocates claim that it's the only way to meet global climate goals, while opponents hold adamant views over safety, security, and radioactive waste matters. However, when one adds SMRs and the military into the mix, things become even more complicated and politically charged. This is because its supporters not only have to take into account the traditional concerns of nuclear energy, but also address worries that relate to the use of SMRs on the battlefield.[23] From a policy perspective, it might also be difficult to secure adequate and sustained funding for SMRs. Given that there are existing substitutes to SMRs, any major SMR program will likely be at the crosshairs of every public budgetary scrutiny and would be the last one to be added and first one to be cut from any spending bill.

Granted, just because there is an uphill battle for the SMR industry, it does not necessarily mean that it's not worth the climb. Given that most Western countries are very much in a nuclear-energy slump, there are sound political arguments to support the idea of the military being the "first mover" in supporting the development of SMRs. By absorbing the initial round of development costs and providing encouragement to risk-averse commercial operators to invest in SMR technology, the military could have a profound impact on the industry. This, by extension, could mean that new jobs might be created, know-how acquired and the foundations of the nuclear energy industry strengthened. After all, many of the West's large militaries have ample experience of working with nuclear energy, and the military in general has often played a key role in spearheading the development of advanced technology, which later was successfully commercialized for civilian use.

Though, it must be noted that the transition from military-grade to civilian SMRs would unlikely be as effortless as it might initially seem. The SMRs used by the military would likely have more robust safety and security features and very different operational requirements than their civilian counterparts. This would likely mean that military SMRs would be vastly more expensive than civilian ones and their electricity would be insufficiently competitive for the civilian energy market.

More broadly speaking, there is also the political risk that if Western nuclear energy companies would not step up their game in developing SMR technology, the industry could likely end up being dominated by Russian and Chinese companies. This could have serious implications for the global nuclear energy market and even beyond. First, given the close links of these governments with state-owned companies like ROSATOM and CNNC, there is good reason to believe that Russian and Chinese nuclear energy exports could be used to pursue broader foreign policy goals.[24] Second, bearing in mind Moscow's and Beijing's close links with a legion of pariah states, some of whom would likely be interested in acquiring SMR technology, there is the risk that SMR sales to these states could inadvertently lead to the weakening of current nuclear non-proliferation regimes.[25]

STRATEGIC MILITARY CONSIDERATIONS

At first glance, SMRs might make a lot of strategic sense for a number of Western militaries. SMRs could greatly reduce the logistical burden of out-of-area missions by "unleashing" the military "from the tether of fuel", as James Mattis, former US Defense Secretary once famously put it.[26]

In practical terms, SMR's might allow the military to cut its fuel bill and help save lives on the battlefield. Evidence suggests that the cost of air-dropped fuel rose up to €340 per gallon when it was delivered to US forward operating bases (FOB's) in Afghanistan.[27] While it is difficult to estimate the electricity cost of military-grade SMRs (as none have yet been built), there are few doubts that it would be markedly lower than the cost of air-dropped fuel. Even more importantly, SMRs would reduce the military's reliance on fuel resupply convoys and the number of troops exposed to roadside bombs and enemy attacks. It was estimated that between 2001 and 2010, over 18,000 US troops were killed in Iraq and Afghanistan during land transport missions.[28] In Afghanistan this may have equaled to nearly one casualty for every 24 fuel resupply missions.[29]

Yet, going forward, it is rather uncertain if there will be an urgent need for any new FOBs. Both opinion polls and the general political sentiment across much of the West clearly indicates that most countries are tired of the so-called "forever wars" in far-flung corners of the world, which over the decades have resulted in hundreds of thousands of casualties and costed trillions of euros.[30] As a matter of fact, it is not very far-fetched to suggest that, at least in recent history, there

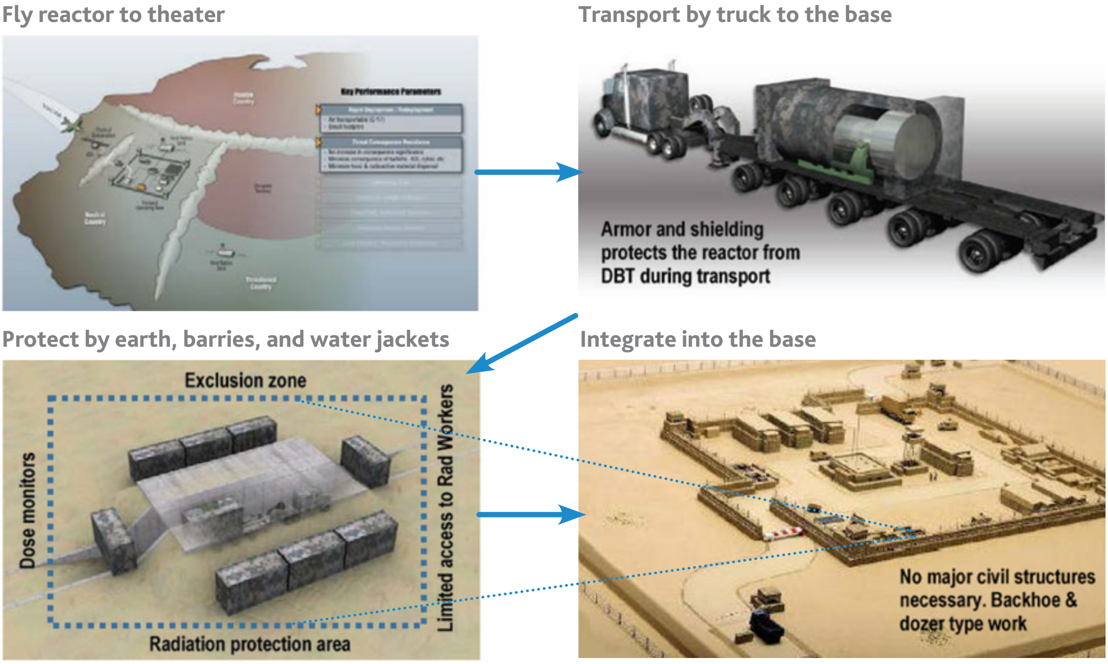

Figure 3. Concept of SMR operations (Credit: US Department of Defense)

has hardly been a time when public support for new boots-on-the-ground and out-of-area military missions was as low as it is right now. Hence, if Western political leadership would be reluctant to get involved in new military conflicts — as it currently very much seems to be the case — or unwilling to extend their stay in places such as Afghanistan or Iraq by a considerable margin, the strategic argument for developing SMRs for the military becomes somewhat nebulous.

Not everyone is convinced that the current distaste for new and large out-of-area missions is a sufficient reason not to develop military SMRs. In 2018, the US Army released a study on the use of the SMRs in ground operations, which, among other things, argued that the SMRs would allow the US to be ready to conduct large-scale combat operations against near-peer competitors, such as Russia or China. More specifically, it claimed that SMRs could support strategic and operational deployment and could "meet the anticipated power demands in both highly developed mature theaters, such as Europe, and immature theaters and lesser developed areas globally."[31]

While there is nothing inherently wrong with the core assumptions of this study, its conclusions do not seem very convincing. For the sake of both national and international security, it is undoubtedly key that the US would be adequately prepared to face near-peer competitors such as Russia and China on the battlefield. But this alone hardly justifies the development of new, costly and unproven energy systems. First, it is widely agreed that, due to a number of reasons, including the risk of a nuclear holocaust, the odds of a large-scale military conflict among the nuclear powers is relatively low. Second, all of Washington's near-peer rivals already possess a wide arsenal of ballistic and cruise missile systems, and are currently developing a new generation of highly accurate and blazingly fast hypersonic weapons.[32] This means that even in the unlikely event of a military showdown, limited or all-out, battle-deployed SMRs would undoubtedly be among the first objects to be taken down by enemy forces.

OPERATIONAL MILITARY CONSIDERATIONS

Whereas at the strategic level the utility of SMRs is somewhat mixed, it is at the operational level that they truly excel. Arguably the greatest military advantage of SMRs relates to its capacity to provide a continuous source of high-density power. Unlike diesel generators, SMRs do not need to be constantly resupplied, and, unlike renewables, the help of additional power storage equipment. Therefore, the deployment of SMRs at FOBs could free up troops that would otherwise have to participate in fuel resupply convoys or have to manage and maintain renewable energy systems.

Considering that SMRs could meet the power needs of even the most power-hungry systems, they would also allow FOBs to expand their operational capabilities. SMRs might provide the necessary energy for additional military hardware, which could include unmanned aerial vehicles, high-power radars, air defense/missile batteries (such as the Terminal High Altitude Area Defense) or other weapons systems. On top of that, SMRs could help the military, and the land forces in particular, to become more future-proof because SMRs would be able to meet the potential energy demand of all-electric brigades, if they would ever come to existence.[33] In a word, SMRs have the potential to act as real force multipliers.

SMRs could also strengthen the energy resilience of bases and military facilities. A significant number of Western military bases are overly reliant on the commercial power grids for their energy supplies. This means that if the central power grids would go down due to cyber-attacks, extreme weather events, human errors or equipment failure, some military facilities would go down too. While virtually all military sites have rigorous emergency power generation plans, which usually involve back-up diesel generators, many military facilities have only enough fuel to last a couple of days. Hence, if there was a prolonged power outage, the operational capacity of the military site could be at risk.[34]

SMRs would address this problem head on. By providing an independent source of power, they could allow the military facilities to enter an emergency "island mode" and stay fully operational even if the central power grid was down.

Granted, a similar effect could be accomplished by substituting SMRs with a combination of smart micro grids, batteries and renewable sources of energy, such as solar or wind power. In the event that the main power grid would go offline, the micro grid could disconnect itself from the main grid and, by relying on either local or on-site energy sources, it could continue to work relatively unharmed. But given the intermittency of renewable energy generation and the current challenges of energy storage technology, SMRs would likely prove to a better option for the military, at least for the foreseeable future.

The operational advantages of SMRs, and especially MMRs, might extend well beyond purely military endeavors. Given their size and mobility, SMRs could be well equipped to assist civilian authorities in humanitarian assistance and disaster relief operations. They might not only quickly provide electricity to disaster-hit areas, but also, in the event of a total blackout (as seen in Puerto Rico in 2018 or Venezuela in 2019) to do a "black start" – a complete reboot of the central power grid.

ECONOMIC CONSIDERATIONS

The economics of SMRs are not as straightforward as one might expect. There is strong evidence to suggest that nuclear energy never made much economic sense. In 2019, the German Institute for Economic Research, has released a survey of 674 nuclear plants that have ever been built to prove that purely commercial considerations have never been the dominant motivation building NPPs.[35] While at a per megawatt hour (MWh) level, NPPs are able to provide one of the cheapest sources of electricity, once the full capital (including the near-ubiquitous construction overruns) and operating costs are factored in, which include dismantling and long-term nuclear fuel storage costs, nuclear energy becomes one of the most expensive sources of energy. For this reason, it is unsurprising that the energy source that was once deemed to be "too cheap to meter" has frequently led its operators into heavy debt or even outright financial ruin.[36]

This mismatch between the electricity costs and the relative popularity of nuclear energy (some

408 reactors are currently generating nearly 10 percent of the world's total energy) can be explained by the presence of other, non-purely-commercial considerations.[37]

First, it makes sense for energy-poor countries, which do not have access to abundant low-cost energy, to develop NPPs. Investments in nuclear energy can provide plenty of electricity, ensure a high degree of energy independence (though most countries still rely on nuclear fuel imports), usually don't require costly and lengthy cross-border transport infrastructure (unlike oil or gas) and also create jobs at the host country (both at the NPPs and the supporting sectors).

Second, there has always been a close overlap between civilian and military nuclear programs. Even though militaries no longer rely on NPPs for their weapons-grade nuclear material, both of these programs depend on the virtually same know-how. Nuclear power and nuclear weapons require similar expertise in engineering, modelling, metallurgy, chemistry, along with scientific expertise in physics and mathematics, just to name a few.[38] Therefore, governments that possess nuclear weapons have a clear reason to maintain a pool of highly trained personnel in the civil nuclear energy sector, so that it would support and maintain their nuclear weapons programs.

Considering that conventional NPPs have not been able to generate electricity at a profit, it seems very unlikely that SMRs would be able to do it either. It is a well-established fact that one of the greatest issues with conventional NPPs are their incredibly long construction times (on average the construction time of a NPP is around 10 years) and capital expenditures – estimated to be between €7.5-10 billion per 1000 MW facility.[39] While civilian SMRs intend to remedy these shortcomings with considerably lower per-unit costs and construction times, the SMRs would lose out on economies of scale.[V] Larger reactors are cheaper on a per MWh basis than SMRs because their material and work requirements do not scale linearly with generation capacity.[40]

Moreover, it is estimated that manufacturers would need to mass produce SMRs by the hundreds, if not by the thousands, to sufficiently keep their production costs low and make the SMRs competitive in the energy market.[41] Seeing that, to date, there has been scant demand for SMRs, and, that there are scores of manufactures who will be competing for a limited number of customers, it is very unlikely that any one of them would be able to dominate the market and significantly cut their per-unit costs anytime soon.

The economic justification of using SMRs at FOBs is similarly built on shaky footing. On a per MWh basis, it is definitely cheaper to supply electricity to FOBs by SMRs than to ship prohibitively expensive canisters of petroleum via air, road or sea. However, if the research, development, construction and the full nuclear fuel cycle costs of SMRs are factored in, the costs of nuclear energy might exceed the costs of shipped petroleum. Unless, obviously, the petroleum is shipped for a very long time, in very large quantities and to very remote locations.

Ultimately, it almost goes without saying that it makes little economic sense to power military bases or other installations, which already have access to the central power grid by an SMR. The cost of electricity at the centralized power grid will nearly always be considerably lower than the cost of electricity from a SMR, especially if it is a MMR.

SAFETY AND SECURITY CONSIDERATIONS

As it is the case with conventional NPPs, the safety and security of SMRs is of paramount importance. If something goes wrong, one might have a nuclear disaster, which could result in widespread ecological devastation, the loss of life and the destruction of property on a truly massive scale. It is also worth noting that in the current political environment, which is marked by a very

[IV] According to the 2020 World Nuclear Industry Status Report, only electricity that is generated at gas peaking plants is more expensive than nuclear energy.

[V] NuScale Power estimates a first-of-a-kind cost for its SMR design of €3.14 billion/1000 MW and an nth-of-a-kind cost of €2.6 billion/1000 MW.

low tolerance for nuclear failures, any major incident at a SMR facility could prove to be a death knell to the nuclear energy industry as a whole.

Safety is one of the main challenges associated with SMRs. The reason is very simple: no civilian or military-grade genuinely land-based SMRs have yet been built or deployed. This contrasts greatly with conventional NPPs with hundreds if not thousands of accident-free reactor years under their belt. Virtually everything that is known about the safety features of SMRs comes from the design plans that have been provided by the companies who intend to build them. Hence, all assumptions about the safety of SMRs should be taken with a great pinch of salt.

According to the developers, SMRs are much safer than conventional NPPs. Many SMR companies have simplified the reactor designs by either reducing the number or completely eliminating pumps, valves and other moving parts, which can malfunction. The new SMR designs have also introduced additional safeguards such as passive cooling mechanisms. All of this, at least in theory, should make the SMRs nearly completely impervious to meltdown. Furthermore, SMRs will have the capacity to be built on land or underground (to make them less vulnerable to external threats, though exposing them to earthquakes) and will be able to operate 3-7 years without refueling (conventional NPPs need to be refueled every 1 or 2 years), with some reactors even designed to operate for up to 30 years without refueling.[42]

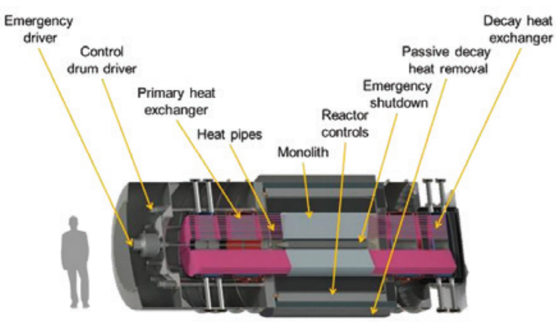

Figure 4. Conceptual Design of the eVinci SMR (Credit: Westinghouse)

To maximize safety and security, and reduce the number of personnel that would be necessary to man the plant, some SMR designs might also be completely sealed shut at the factory, only to be reopened once the SMR is brought back to the factory for refueling.[43]

Regardless how good it sounds on paper, there are some glaring safety concerns with these sealed SMRs designs, particularly those which would likely see heavy use on the battlefield. Taking into account that many SMRs will have to be shipped over long distances and rough terrain to reach a FOB, there exists the chance that the SMR might be damaged during the journey. Because no one would be able to open the SMR and inspect its interior before it gets connected to a power grid, there is a possibility that the reactor might malfunction. While these SMRs would doubtlessly be equipped with multiple high-tech reactor-monitoring sensors, this would still not be a completely fail-proof way to ensure the safety of its end-users. After all, the possibility exists that the sensors themselves could be damaged during the trip or would malfunction, making their data unreliable or outright unavailable.

Battle-deployed SMRs might also become the targets of hostile actors. If recent decades are a guide, many FOBs would be likely located in, or near, countries that are home to hostile insurgent groups. In turn, these installations would be frequently subject to weaponized drone and missile strikes or mortar attacks, making SMRs extremely high-value targets. Even if the odds are rather slim that the SMR could be outright destroyed, the risk still exists that it could be buried by debris or damaged to the extent that it could no longer cool itself.[44] If the SMR would be unable to prevent its temperature from rising and it would not be possible to open the reactor, inspect it and repair it, the forces stationed at the FOBs could be facing the prospects of an imminent nuclear meltdown, without even knowing it.

The SMRs at FOBs could also be at risk of being captured by the enemy. This would either contribute to the proliferation of nuclear weapons, or, alternatively, allow a terrorist organization to build a dirty bomb by using its spent fuel. The latter could be a particularly serious concern if the SMR uses high-assay low-enriched uranium (not to be confused with highly enriched uranium), as it is the case with a number of MMR designs under development.[VI]

Though, admittedly, the likelihood of nuclear theft from FOBs is probably much lower than it is generally believed. Spent fuel is essentially "self-protecting" due to very high levels of radioactivity and FOBs tend to have very stringent security standards, making them difficult to be overrun.[45]

ENVIRONMENTAL CONSIDERATIONS

At first glance, SMRs can provide very clear environmental benefits to the military. Most armed forces around the world are major consumers of fossil fuels and, therefore, are responsible for large amounts of greenhouse gas emissions. In fact, a recent Brown University study has revealed that the US military is the country's largest institutional consumer of petroleum and correspondingly, the single largest institutional emitter of GHG in the world. It was responsible for 59 million metric tons of GHG emissions in 2017.[46] These emissions were the result of not only military operations, but also of on-going non-war operations and maintenance of military installations. To put it in perspective, the US military's GHG emissions in 2017 were greater than the emissions of countries such as Sweden or Denmark.

This is by no means a unique US military problem. It just so happens that it is by far the largest military in the world with the most active missions around the globe. Most other Western militaries suffer from the same faults and, in relative terms, are equally significant consumers of petroleum. This means that they too are responsible for a significant share of GHG emissions.

While in recent years Western militaries have sought and to an extent succeeded in becoming more "green" and environmentally friendly by investing in alternative fuels and improving energy efficiency, it is generally agreed that they still have a very long way to go. The fact that there has been a longstanding international convention, which has caused many governments around the world not to report on the GHG emissions of their militaries, let alone include them within national targets, has not helped the cause either.[47]

Fortunately, SMRs could provide the military a helping hand in its fight against climate change. Unlike fossil-powered power plants, SMRs produce electricity via nuclear fission rather than combustion. SMRs do not cause air pollution or produce any GHGs while operating. Therefore, if Western militaries would adopt SMRs in large numbers, they could seriously decrease their petroleum consumption and cut their GHG footprint.

Granted, virtually no militaries could fully substitute petroleum with nuclear energy because the bulk of their petroleum is used for operational purposes i.e. the actual use of planes, ships and vehicles. And it does not seem very likely that the military could go all-electric anytime soon. But if nuclear energy could replace even a tiny fraction of the petroleum that is used for non-war operations or the maintenance of bases or installations, that would still be a commendable achievement for the military.

While all of this sounds great, there is one major drawback with SMRs that it shares with conventional NPPs: nuclear waste. According to the Stimson Center, a US think-tank, some 400,000 tons of highly radioactive spent fuel has been stored at hundreds of sites across dozens of countries since the 1950s. The amount of spent fuel in storage is expected to continue to grow and, it is estimated that, on average, the global spent nuclear fuel stockpile will increase by around 11,000 tons annually.[48]

Despite the fact that commercial NPPs have been in operation for more than sixty years, the issue of spent fuel has arguably been insufficiently ad-

[VI] Most existing nuclear reactors run on uranium fuel that is enriched up to 5% with uranium-235 — the main fissile isotope that produces energy during a chain reaction. In contrast, high-assay low-enriched uranium (HALEU) is enriched between 5% and 20%. This is done to allow reactors to get more power per unit of volume. It is also believed that HALEU will allow reactors to have longer core lives, increase their efficiency and ensure better fuel utilization.

dressed so far. Given its highly radioactive properties, spent fuel must be stored for thousands of years, but to date, no country in the world has yet built a deep geological repository where the fuel could be stored for the long haul. Finland is the only country that is currently constructing a permanent repository for this type of nuclear waste.[49] In the meanwhile, all of the other countries have largely pursued interim strategies by building temporary facilities for spent fuel storage purposes.

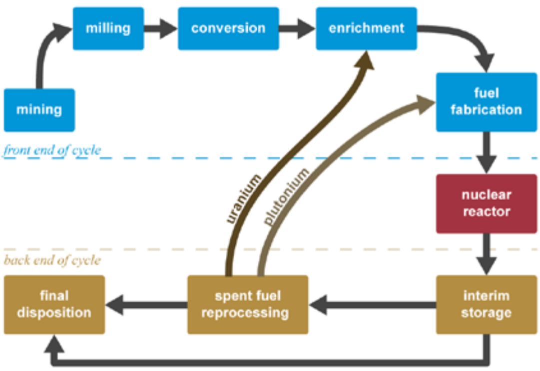

Figure 5. Nuclear fuel cycle (Credit: US Energy Information Agency)

Certainly, it is possible to reprocess some of the spent fuel by recycling usable portions of the fuel for secondary use. And countries like France and the UK have done this with considerable success. Yet, this is a very difficult and expensive process, which alone could unlikely address the world's growing nuclear spent fuel stockpile. In fact, a single reprocessing plant with a meaningful annual recycling capacity may take decades to build, can cost many tens of billions, and this sum may not even include the operational or the decommissioning costs of the plant itself.[50]

REGULATORY CONSIDERATIONS

Whereas there are fairly few purely technical obstacles for the development and deployment of SMRs, there are serious regulatory challenges that would still need to be addressed. Unlike civilian SMRs, which would likely be subject to the same or similar regulations as conventional NPPs, military SMRs would likely need to receive special treatment so that they could reach their intended potential. Yet, this is something that is easier said than done.

Considering their niche applications and unique operational requirements, it is uncertain who would be responsible for regulating the work of the SMRs. On the one hand, the majority of the world's existing civilian NPPs are regulated by mostly independent governmental bodies, which, among other things, oversee reactor safety and security, administer reactor licensing, the storage and the disposal of nuclear fuel. On the other hand, it might make sense that SMRs, which would be specifically designed for the battlefield or for large military installations, would be regulated by the military itself. After all, it is only reasonable to assume that they would know better than anyone the operational needs of their own facilities.

However, there are several problems associated with self-regulation that cannot be ignored.

First, militaries would unlikely have the personnel with sufficient expertise to act as regulators. Unlike nuclear reactors that are used by the navies, the regulation of land-based SMRs would likely be a much more complicated task, given that the military would have to take into consideration a much broader specter of safety and security issues, and deal with many more stakeholders. While, obviously, this is not an unsurmountable obstacle, in most countries it would likely take years and huge amounts of resources for the military to develop a level of expertise on par with the civilian regulators.

Second, even if the military would agree to self-regulate its SMRs, it would likely inherit all the unenviable tasks that are associated with managing nuclear energy. Taking into account that it would be responsible for issuing the licenses for the reactors, the military would likely receive a fair share of the blame and might be even liable for some of the damages in the event of a nuclear accident. Self-regulation might also mean that the military would have to shoulder the decommissioning and waste disposal costs, both financial and time-related. That would not only provide additional strain on its budget, but also create an institutional nightmare as no nuclear energy company, or even any government for that matter, has yet managed to conclusively address the question of spent fuel.

The alternative to self-regulation for the military is also not very appealing. If things remain as they are and SMRs would be regulated by governmental bodies in line with existing safety and security standards, these SMRs would likely be subject to the same or very similar licensing requirements as conventional NPPs. This means that the developers would have to take into consideration factors as varied as geology, seismology, population density, emergency planning, ecology and biota for each and every SMR proposal. As a result, even if the licensing process would be accelerated by a significant margin (if compared to conventional NPP licensing), it might still take years for a single license to be issued. This would, by definition, undermine the whole point of having readily deployable SMRs, and especially the highly-portable MMRs.

Regulatory matters could also greatly complicate SMR deployment efforts. According to existing international law, foreign-deployed SMRs would likely be subject to a plethora of rules that regulate the handling of nuclear material and seek to reduce the risk nuclear proliferation.[51] SMRs would have to respect the domestic laws of the host country, too.[52] Yet, since nuclear energy is a relatively sensitive topic, it is not that difficult to assume that some governments of would-be host countries could be, due to political or other reasons, unable or unwilling to issue a permit for the deployment of a SMR. Thus, the regulator, whoever it may be, would have to pursue a fine balancing act of meeting various international agreements and respecting the laws of host countries, all while ensuring the operational flexibility for the SMRs.

In light of these constraints, leading SMRs developers have publicly advocated to relax some of the regulatory requirements. They argued that existing nuclear regimes, their supporting treaties, and other international agreements have not kept pace with progress and that they are fashioned to support conventional NPPs and not SMRs.[53]

To an extent, the developers are right. Many of today's safety and security regulations are geared towards traditional NPPs, and even the IAEA seems to agree that some adjustments might have to be made to accommodate the needs of the SMRs industry.[54] Especially because there is the real risk that heavy-handed regulation could strangle the SMRs industry before it had the chance to really get going.

But there's also the other side of the coin. Despite the confidence of the developers, SMRs still remain a fundamentally unproven technology and it will take years of rigorous testing before they could be deemed to be at least as safe as conventional NPPs.

CONCLUSION

Small modular nuclear reactors are a promising technology that one day may very well power Western militaries. They not only could contribute to military operations by increasing energy assurance, reduce the military's reliance on fossil fuels, but also help cut greenhouse gas emissions. In fact, it would not be an overstatement to suggest that SMRs, and especially the highly-portable micro modular reactors, could prove to be a truly game-changing technology both for military applications and civil use. From a political point view, their development might also make a lot of sense because it could help strengthen the Western nuclear energy industry and prevent the weakening of global nuclear non-proliferation standards.

However, SMRs also pose some serious questions that have to be tackled by political and military leaders alike. Given that SMRs would unlikely make much economic sense anytime soon, it would only be reasonable to develop SMRs if militaries would actually intend to use them. In other words, the full benefit of SMRs could be seen if Western leaders would genuinely be determined to launch new missions to remote places with little-to-no access to electricity. Or, alternatively, if they would be willing to extend existing out-of-area missions for years and years to come.

In the event that Western leaders would become convinced that there was a clear strategic need to deploy SMRs, both the militaries and the SMR developers would have to carefully think about other, less high-brow matters. First, they would have to ensure that the SMRs would be sufficiently robust to survive a battlefield environment and not put its personnel at unnecessary risk. Second, they would have to carefully consider all the regulatory obstacles associated with SMRs, especially if there would be any plans to ship them to foreign countries. Few things would be more damaging to the reputation of the military than the inability to deploy SMRs in the way they were intended to be. Third, the issue of spent fuel would have to be addressed. If Western militaries really want to burnish their green credentials, they should help address the issue of spent nuclear fuel and prove that they would be part of the solution and not the problem.

Only if these matters are properly dealt with, it would make sense to invest in military SMRs. Otherwise, there is the very real risk that, despite its enormous potential, this technology could one day become as much a liability as an asset.

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Hybrid warfare against Critical Energy Infrastructure: **The Case of Ukraine***

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ANNOTATION

This study identifies and analyses the success of different hybrid warfare tools used by Russia in the Ukrainian energy sector between 2014 and 2017, namely different types of malicious acts against critical energy infrastructure, the implication of these events for Ukraine and the lessons to be learned for NATO security.

INTRODUCTION

Ensuring the uninterrupted functioning of energy systems is among the most important issues facing every country. This mission is not a new one and measures have been developed to secure critical energy infrastructure – facilities, services, information and industrial control systems so vital that their denial or destruction would have a significant impact on national security, economy, government and well-being of society. However, Russia's aggression against Ukraine and the challenges it has brought[1] have raised the question of whether there is a need to rethink the 'energy dimension' of modern warfare.

This study seeks to answer the question. It aims to determine whether it is necessary to review the existing approach to ensuring the protection and resilience of critical energy infrastructure throughout the Alliance. The case of Ukraine is unique – it is a country at war whose political, legal and economic conditions are, or until recently have been, very different from those of NATO Nations. Any lessons learned will thus take this difference into account.[2]

The conflict in Ukraine is often referred to as an example of hybrid warfare, where conventional methods of fighting do not play a primary role. Instead, an expanded use of the tools of political and economic pressure comes to the fore, including information warfare and psychological operations built on disinformation and propaganda.

In Russia, these methods are called 'New Generation Warfare'. Their objective is to achieve superiority over the enemy's armed forces and civilian population through moral and psychological means. Such an approach seeks to minimise the need for deploying hard military power and in-

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[1] They include preparation for and destruction of critical infrastructure; weakness of security systems and the armed forces of Ukraine; inefficient coordination between agencies; inability of the international community to secure the guarantees given by the Budapest Memorandum of 1994 to Ukraine; usage of unconventional tools of warfare; informational attacks against Ukraine to spur an economic crisis; rise in criminal activity.

[2] Please note that the NATO Energy Security Centre of Excellence will publish the main lessons learned in a separate document.

stead attacks its opponents "hearts and minds" (Berzins 2016:2). The intention is to create an atmosphere of mistrust, doubts and insecurity within a society. It also aims to disrupt the unity and cohesion of alliances and to cover up the aggressor's real objectives (Nissen 2016:3).

This paper is organised as follows. Firstly, it assesses Russia's use of energy as a political weapon during the pre-conflict period. Secondly, it examines attacks on energy infrastructure during the 2014-2017 period of conflict in Donbas, distinguishing between energy assets that are critical and those that are not. Thirdly, it surveys energy-related events in the rest of Ukraine. Finally, it offers lessons learnt and proposes measures to enhance the resilience of the energy sector.

1. USE OF ENERGY AS A TOOL OF RUSSIAN FOREIGN POLICY DURING THE PRE-CONFLICT PERIOD

The use of energy for political purposes has a long history in Russia's foreign policy. It was openly proclaimed in 2003 in the Energy Strategy of the Russian Federation for the period up to 2020, which states that the fuel and energy complex of Russia "is the basis of economic development, a tool of domestic and foreign policy making".[3]

Energy, especially supplies of natural gas, has served Russia as a tool to advance its objectives with respect to both Ukraine and NATO Nations in the period preceding the crisis in Ukraine and, in some cases, subsequently. The methods employed include imposing unfavorable commercial terms and conditions onto countries, attempts to create or expose corruption and political pressure to achieve desired foreign policy objectives. However, Russia's ability to use energy for political purposes has declined. Thanks to market liberalisation, improved interconnectivity and import diversification, NATO Nations are now less vulnerable to Russia's energy pressure.

In trying to keep Ukraine in its sphere of influence, Russia employed a range of tools: monopolising the gas market by blocking the entry of new suppliers; denying access to pipelines coming into Ukraine from the west via Slovakia, Poland and Hungary [1, 2]; obstructing reforms of Ukraine's gas market by insisting on long-term prices in contracts, 'take-or-pay' and re-export prohibition clauses; offering gas price discounts in exchange for political concessions; taking measures designed to corrupt government officials and corporate managers. The involvement of intermediaries in the gas trade between Russia and Ukraine created a wide range of supporters of non-transparent gas market readily lobbing for Russian interests.[4, 5]

The most striking examples of this policy are: corruption of officials in 1998-2005 that led to the signing of unfavorable contracts for natural gas supplies in 2009; gas price discounts in exchange for the extension of a long-term lease of the naval base in the Ukrainian Black Sea port of Sevastopol in 2010; rejection of the Association Agreement between Ukraine and the EU while securing the promise of additional loans from Russia for the purchase of gas in 2013.

Another example of the political use of energy is the case of supplies of nuclear fuel to Ukrainian nuclear power plants (NPPs). Russian experts and politicians claim, falsely, that the "use of fuel assemblies produced in America will inevitably raise the risk of Ukrainian nuclear reactor failures and increase the probability of man-caused disasters that would be comparable to the Chernobyl accident" [3, 4, 6, 7].

Another example involves spent nuclear fuel[6]. An

[3] Energy Strategy of the Russian Federation for the period up to 2020 (in Russian). Access: http://www.cpnt.ru/userfiles/_files_normativ_energosafe_energostrategy.pdf

[4] Balmaseda M. (2008). Energy Dependency, Politics and Corruption in the Former Soviet Union: Russia's Power, Oligarchs' Profits and Ukraine's Missing Energy Policy, 1995-2006. Routledge.

[5] Sukhodolia O. Chapter 3.4 and 7.4 in book: The Global Hybrid War: Ukrainian Front. / monograph under the General Editorship of V.Horbulin (in Ukrainian). K.: NISS, 2017. – 496 p.

[6] Energy Strategy of Ukraine as the Instrument of Energy Security Politics. Conference information package under the general editorship of O. Sukhodolia. Kiev: NISS, 2014. – 168 p. (in Ukrainian). D. Bobro "Aspects of development of nuclear-power engineering in the context of providing energy independence and sovereignty of Ukraine". p.60-70. Access: http://www.niss.gov.ua/content/articles/files/Druk_Cyxodolya_Bezpeka_31_08-e5ff5.pdf

attempt by Ukraine to construct its own spent fuel storage facility created a strong reaction in Russia [7, 8]. Because of the allocation of land for the facility, Russia's information machine accused Ukraine of trying to build a nuclear bomb and use it against Russian cities[7]. These claims were repeated by some European experts and Ukrainian individuals [9, 10, 11, 12]. While spent nuclear fuel can be made into a 'dirty bomb' if the material is placed within a conventional bomb, Ukraine signed up to and respects IAEA standards on spent nuclear fuel storage.

Such statements on the part of Russia, also repeated by some members of the Ukrainian political elite, are aimed at the destabilisation of society through a demoralisation from inside and reinvigorating the deep rooted fears of another accident of the extent of Chernobyl [13,14,15,16]. Fake news about committing acts of sabotage at Ukrainian NPPs or subversive activities with radioactive materials by Ukraine are possible scenarios for future attempts at destabilisation of the situation in Ukraine.

Hybrid methods of warfare, including those that target the energy sector, are being employed by Russia not so much as to defeat the armed forces of Ukraine, but to put pressure on the state leading to the overthrow of its government and its replacement with one loyal to Moscow. Russia seeks to attain this goal by trying to worsen the population's living conditions, forment discontent with authorities, demoralise society and undertake a concerted effort to foster chaos in the country's government and its economy. It is clear that in almost six years of trying to win a hybrid war, Russia has not succeeded – Ukraine's government has not been replaced with a pro-Moscow one.

2. OVERVIEW OF EVENTS DIRECTLY RELATED TO THE DISRUPTION OF CRITICAL ENERGY INFRASTRUCTURE IN THE PERIOD 2014-2017

Russia's direct use of the energy sector as a weapon in the pre-crisis period (up to 2014) contributed to the inclusion of the energy dimension in the present concept of hybrid warfare. During the period between 2014 and 2017, a series of energy related events led to internal disruptions in Ukraine.

It should be noted that Russia mentioned the importance of subversive activities as early as 2014. The seizing of energy infrastructure and resources in Ukraine represented a first step in the energy dimension of the conflict, with Russia targeting energy facilities in Crimea and later in some districts of the Donetsk and Luhansk regions. Actions of this type are described in detail in section 3.1 below.

Kinetic methods of adversely impacting important infrastructure were used often and included demolitions and shelling, which caused damage to coal mines and heat and power generation facilities, as well as water, gas and power supply systems [1, 2]. Specific examples are provided in sections 3.2 & 3.5 below.

Along with the destruction of transport infrastructure in the occupied part of Donbas, Russia also resorted to the blocking of transport infrastructure on the border between Ukraine and Russia. At the same time, railway lines and bridges on the line of conflict and further inland were detonated and coal supplies from Russia were blocked on the border in order to stop coal supply to thermal power plants of Ukraine.[8] Details are available in section 3.6 below.

In 2015, the 1st Assault Engineer & Sapper Battalion was formed by the Russian army. According to the chief of Russian engineering troops, its task was to destroy fortified facilities in the field and in urban environments [3]. A similar unit, tasked to carry out reconnaissance and sabotage operations and capture strategically important

[7] In his interview to the Russian newspaper Komsomolskaya Pravda in late October 2016, Sergey Markov, a Russian political scientist, said that the refusal of Ukraine to send spent nuclear fuel to Russia for reprocessing was evidence of the fact that Ukraine was building a nuclear bomb, or at least a 'dirty bomb'. In his judgment, Crimea, Donbas and big Russian cities including Rostov, Voronezh and Belgorod could come under attack.

[8] Nearly a half of Ukrainian thermal power plants operate on anthracite. Its production in Ukraine is concentrated in the Donbas areas that are not controlled by Ukraine.

objects, was formed by Russia on the occupied territory of Ukraine [4]. Later, Vladimir Putin conferred the leaders of those units with special honors in the Kremlin [5, 6, 7].

Some pro-Russian activists suggested undermining the new government in Kyiv by damaging critical energy infrastructure (CEI). They proposed three possible targets: the 750kV transmission line from south Ukrainian NPPs, the 750kV line from the Donbas region to western Ukraine and the 750kV line from Zaporizhzhya NPP. However, they have been unwilling or unable to carry out an attack. In any case, sabotaging the transmission lines would not endanger the life of the population directly as power plants are designed to manage such power cut scenarios. Although some NPPs that rely on off-site energy for cooling might struggle to manage the process, most NPPs would be able to shutdown safely under their own power.

A direct kinetic attack against a NPP would induce fears of radioactive contamination. An initial cyber attack would make a kinetic attack against a NPP easier as many remote control systems would have to be switched to manual control. However, it is highly unlikely that insurgents in Donbas posses the know-how to launch a cyber attack against a NPP. Such an attack would need to come from Russia. It would be a highly risky move on the part of Russia – it would break the existing taboo on malicious use of nuclear energy and could endanger its own population as radioactive dust could fall on Russia. As a result, the scenario of a combined cyber-kinetic attack against a NPP, designed to cause radioactive release, is unlikely.

A more realistic scenario is an artillery or other kinetic attack on the facilities of the water supply system at Zaporizhzhya thermal power station or Zaporizhzhya NPP, which might cause their shutdown and result in a blackout of the entire United Energy System of Ukraine.

In the face of various threats, Ukraine had to take measures to strengthen the security of its key strategic sites, particularly its nuclear power plants [9] [8, 9, 10, 11, 12, 13]. This applied especially to the Zaporizhzhya NPP, which lies in proximity to the fighting zone. Zaporizhzhya NPP was strengthened by measures ensuring air defense and protection from tank breakthroughs [14] as well as revising Design Based Threat for NPPs that prescribed additional measures for protecting NPP sites [15].

An example of political pressure being exerted by Russia on the Ukrainian government through economic and energy means involves the ongoing debt disputes between two state-owned companies: Naftogaz of Ukraine and Gazprom of Russia. Naftogaz and Gazprom lodged several demands against each other regarding debt claims over natural gas purchases and their pricing contracts. In May 2017, an arbitration court invalidated the 'take-or-pay' obligation that Gazprom had insisted on, demonstrating that Russia's use of energy for political purposes can backfire on Moscow.

Existing tensions between the population and the Ukrainian government were further exploited and fueled by Russian information campaigns, which attempted to convince the population that the government was unable to ensure a stable national energy system with continuous supply of gas, heat or electricity (Sukhodolia, 2014). At the same time, considerable criticism of governmental actions with regard to reforms in the energy sector was also underway. This especially applied to liberalisation of pricing in energy markets and reforms in the subsidy system. Nevertheless, Russia's information campaigns have largely failed in the face of reality – Ukraine's energy sys-

[9] In August 2016, the Security Service of Ukraine defined the level of terrorist threat in the Mykolaiv region as "yellow" (projected threat). It was decided to step up security measures at the South Ukraine NPP located in this region, since nuclear fuel of Westinghouse Corporation is in operation in its Unit 3. Another example could be the commencement of criminal proceedings in November 2016 under Art. 111 of the Criminal Code of Ukraine ("Treason"), Art. 113 of the Criminal Code of Ukraine ("Diversion") and Art. 255 of the Criminal Code of Ukraine ("Establishment of a criminal organisation") based on alleged illegal activities of the staff of Zaporizhzhia NPP, who had links with Russia.

tem continues to function, reforms continue to make gradual progress.

3. ACTIONS UNDERTAKEN AGAINST ENERGY INFRASTRUCTURE

Based on the analysis of events, the actions against Ukrainian energy infrastructure can be divided into two main groups. The first group is *unintentional actions*, where disruption is an 'accidental' consequence of fighting (Collateral damage). In our understanding, unintentional actions constitute the majority of cases and are the main cause of damage in the Luhansk and Donetsk regions.

The second group is *targeted acts* aimed at the deliberate destruction or denial of various energy functions. Among the cases of deliberate physical actions[10], the following groups of actions should be highlighted:

- physical seizure of facilities which are kept in operation; an example here is occupation of energy assets in Crimea;
- termination of the facilities' operations, including their physical occupation, with the purpose of inflicting losses on the previous owner or for an 'exchange' for potential benefits in other domains (satisfaction of political or economic demands), an example here is the case with the supplies of anthracite coal from the occupied territories and from Russia to the Ukrainian TPPs;
- physical destruction of facilities in order to inflict critical damage to vital services (delivery of fuel, water, food and medicines to the population and the armed forces) and increase the costs of recovering and repairing damaged infrastructure;
- hindering efforts to restore the operability of energy infrastructure in order to create social and political discontent of the population;
- dismantling of some infrastructure elements for the purpose of obtaining criminal proceeds.

Disrupting and destroying energy infrastructure can have severe consequences not only for the impacted population, but also for the sectors which depend on functioning energy systems for their own operation. The physical distruction of expensive and bulk power equipment such as large power transformers (LPT) are not only expensive to replace but can take months to procure, manufacture, transport and install[11]. An attack on the energy grid thus can cause cascading effects across all sectors of critical infrastructure that require electric power with potentially devasting effects on modern economic activity, national security and well being of society.

3.1. SEIZURE OF ENERGY ASSETS

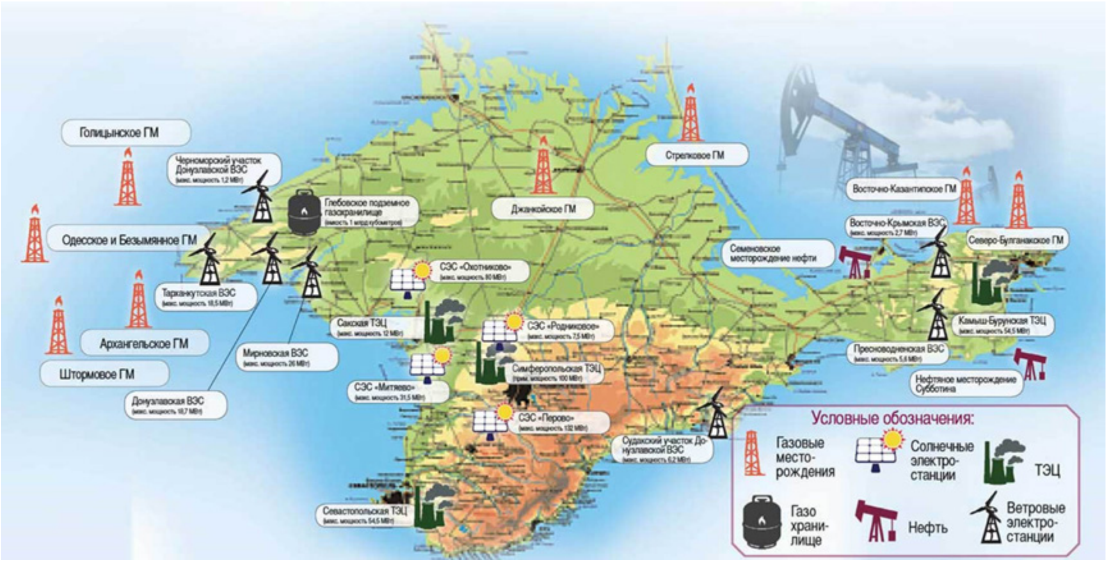
During its invasion of Crimea, Russia promptly and purposefully captured energy infrastructure, resulting in Russian control over energy companies in Crimea. Crimean administrative buildings were occupied and orders for re-subordination of all energy facilities were given from there [32, 33]. At the same time, the Parliament of Crimea nationalised some national energy enterprises of Ukraine by its decision of March 17, 2014 "On the issue of energy security of the Republic of Crimea" [34]. Energy assets were seized not only in Crimea, but also in the Black Sea shelf area (energy facilities and deposits of gas and oil resources) and later in Donbas (mines, power plants, pumping and compressor stations and pipelines).

Both state-owned and private power generating facilities were seized, including several combined thermal power stations (TPP) with a total capacity of 144.5 MW; wind power plants with a capacity of over 60 MW; solar power plants with a capacity of over 224 MW; trunk transmission lines with a total length of 1,370 km; 17 transformer substations of 110-330 kV with a capacity of 3,840 MVA; distribution power lines with a total length of 31,900 km; 270 transformer substations of 35-110 kV with a total capacity of 6,028 MVA. The total value of assets lost in Crimea by just NEC "UkrEnergo" alone is estimated at ap-

[10] Sukhodolia O. Problems of protecting energy infrastructure under the conditions of hybrid war (in Ukrainian). Access: http://www.niss.gov.ua/articles/1891/

[11] See "Large Power Transformers and the U.S. Electric Grid", U.S. DoE June 2012. https://www.energy.gov/sites/prod/files/Large%20Power%20Transformer%20Study%20-%20June%202012_0.pdf

Figure 1. Energy assets lost by Ukraine as a result of the annexation of Crimea by Russia.



proximately USD 1 billion [35]. The rest of the Ukrainian energy system, however continued to fuctioin after these losses.

Additional losses included assets in the oil and gas sectors, particularly those belonging to state-owned companies. For example, the state represented by the National Joint Stock Company Naftogaz of Ukraine owns 100% of shares of the State Joint Stock Company Chornomornaftogaz, which included capital equipment and mine infrastructure (10 offshore gas production fixed platforms, 4 drill units including "Sivash" "Tavrida", "Petr Godovanets" and "Nezalezhnist"), infrastructure of gas transport and storage (gas transportation system with 1,200 km of trunk pipelines and 45 gas distribution stations, as well as "Glibovske" underground gas storage with active capacity of 1,5 bcm)[12].

Ukrainian losses in Crimea are schematically shown in Figure 1 below. Details of seized assets are given in Appendixes 1 and 2.

3.2. DESTRUCTION OF POWER PLANTS AND THEIR DISCONNECTION FROM THE UNIFIED ENERGY SYSTEM OF UKRAINE

The Unified Energy System of Ukraine (UESU) includes eight power subsystems. Two of them – in Crimea and a part of Donbas – are disconnected from the UESU. Due to the availability of sufficient reserves in generating capacity, this disconnection has not directly impacted the operation or stability of the UESU.

Neverthless, in Donbas the destruction of power plants and power lines reduced power supply to consumers in some areas of the Donetsk and Luhansk regions which are not controlled by the Ukrainian government, as well as to consumers in the territory controlled by the government near the front line [36].

In close proximity to the fighting lines are the Luhansk TPP in Shchastia city (1.4 GW), the Vuhlehirska TPP in Svitlodar city (3.6 GW) and the Myronivska TPP (0.2 GW) in the Svitlodar region.

[12] On 10 October 2014, the Prosecutor General of Ukraine made a record in the Unified Registry of Prejudicial Investigations for the illegal appropriation of Chornomornaftogaz property. This is based on a criminal offense specified by clause 3 of article 206 of the Criminal Code of Ukraine and for illegal extraction of natural gas by officials of Chernomorneftegaz, based on a criminal offense specified by clause 2 of article 240 of the Criminal Code of Ukraine. The company's value could thus be estimated at a figure close to $1 billion based on its projected output over the time span of 15 years.

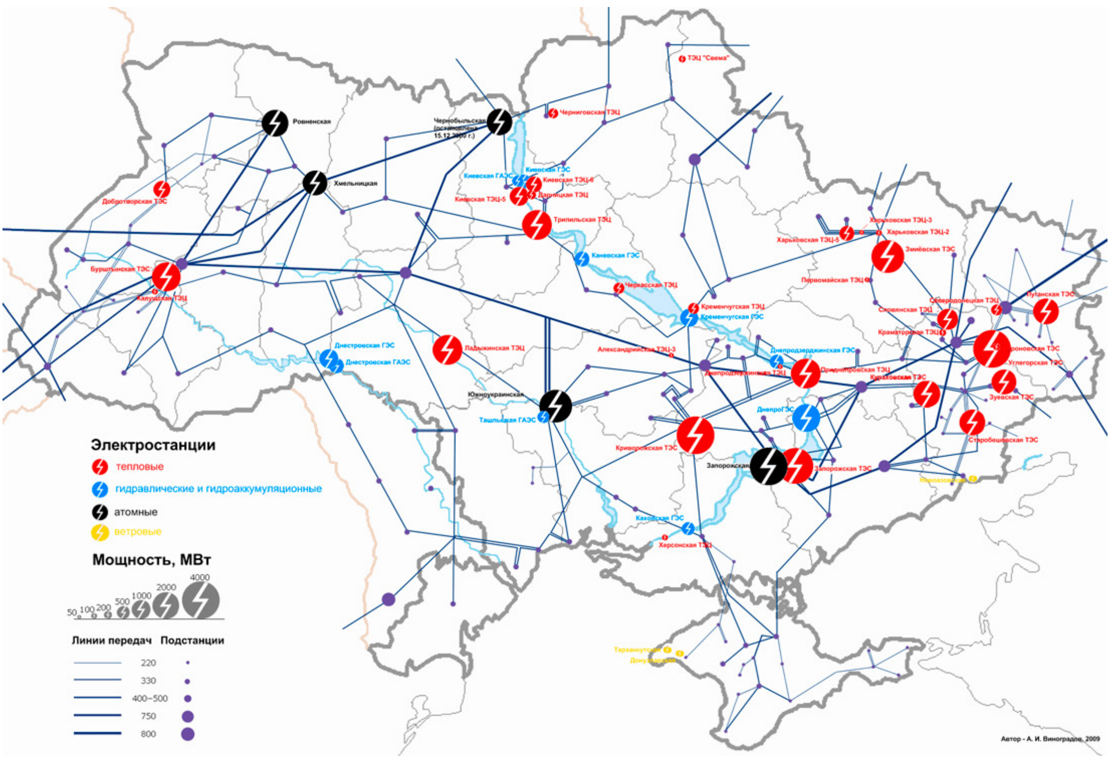
In 2014 the fighting zone included also the Slovianska TPP in Sloviansk city (0.88 GW).

Stoppages at the Slovianska and Vuhlehirska TPPs, caused by shelling, complicated the supply of electricity across all of south-eastern Ukraine. The Luhansk TPP regularly came under fire during the summer of 2014. Repeated shelling caused a full shutdown of the plant followed by the loss of generating capacity and consequent disruption of power supply to the northern part of the region, which remained under the control of Ukrainian forces.[13] Table 1 on the following page provides more information about various attacks.

3.3. ATTACKS ON TRANSFORMER SUBSTATIONS AND ELECTRIC POWER LINES

Damage to power supply systems resulted in large-scale interruptions of power supply. Damage to transformer substations and power lines interrupted the electricity supply between certain areas and the unified system, thus leaving consumers dependent on a single source of power. In 2014-2015, transformer substations were repeatedly de-energised, which led to blackouts in large cities such as Luhansk and Donetsk.

Figure 2. Layout of UESU. Details on the eight UESU subsystems and Thermal Power Plants of Ukraine are provided in Appendix 5.

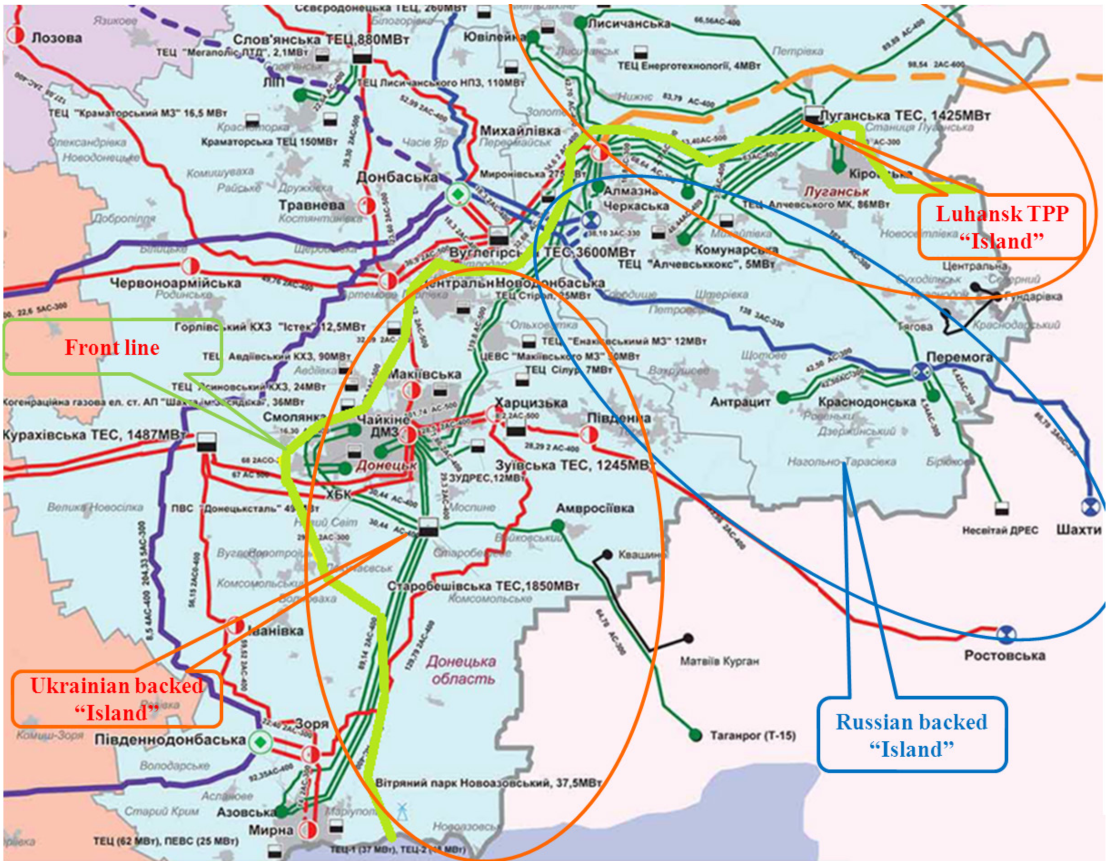


[13] The damage to the Luhansk TPP was the most critical for Ukrainian government because it is the only source of electricity supply for the whole Luhansk region. Currently the Luhansk TPP (fueled by anthracite type coal) is the heart of the 'Luhansk TPP island' (fig. 3) that functions separately (is disconnected) from UESU. Only two lines from the Luhansk TPP feed government controlled territory. Any damage of the TPP, plant transformers or these two lines would de-energise the northern part of the region. Most of the power lines from the Luhansk TPP go to the occupied territory (most of them to the transformer substation "Novomykhailivka" and two to Luhansk city). They cannot be operated by Ukraine. The lines to the substation "Novomykhailivka" are damaged and are blocked from restoration by separatists. Therefore, out of the total 1.4 GW capacity, only 3 units (300 MW) work and provide electricity to both the government controlled and the occupied territory.

Table 1. Examples of damage caused to TPPs, as recorded by the OSCE SMM

Date of attack	Location	Details of the impact	Possible attacker	Link
July 3, 2014	Slovianska Thermal Power Plant (Sloviansk city)	The TPP came under shelling. As a result, its fuel tank and two transformers were damaged. This caused the shutdown of the last two operating transmission lines. Finally, after heavy shelling, the TPP's operation was stopped till the end of the year.	Damage was caused by mortars (120mm, 82mm and "Nona"), artillery system (23mm), underbarrel grenade launcher (VOG-25 & VOG-17), MLRS "Uragan". The rounds had been fired from "DPR" controlled territory.	37, 38, 39, 40, 41
01.02.2015	Slovianska Thermal Power Plant (Sloviansk city)	The SMM heard continuing incoming heavy artillery fire impacting in the vicinity of the Shchastia power plant.	unknown	42
17.09.2014	The Luhansk Thermal Power Plant (Shchastia city)	Damage of a transformer that caused a temporary blackout in the area.	Damage was caused by mortars that were fired from "LPR" controlled territory.	43, 44, 45, 46
28.05.2015	The Luhansk TPP (Shchastia city)	Heavy-machine gun fire damaged equipment and caused a temporary blackout in the area.	Damage was caused by heavy-machine gun that fired from "LPR" controlled territory.	47
04.07.2015	The Luhansk TPP (Shchastia city)	Damage of equipment as a result of shelling.	Damage was caused by mortars 82mm and howitzer 122mm that fired from an easterly direction. (*"LPR"controlled territory*)	48
15.07.2015	The Luhansk TPP (Shchastia city)	In Shchastia (government-controlled) the SMM heard two distant explosions in the vicinity of the power plant.	unknown	49
05.08.2015	The Luhansk TPP (Shchastia city)	Shelling was on-going in Shchastia	unknown	50
27.07.2015	Vuhlehirska TPP (Svitlodarsk city)	Critical elements of TPP were damaged by the shelling.	Damage was caused by mortars and artillery system (122 and 152mm).	5, 5, 5, 5, 5, 5
17.08.2016	Vuhlehirska TPP (Svitlodarsk city)	Damage of TPP's infrastructure objects.	Damage was caused by an artillery system (152mm).	57
January 2015	Mironivska TPP (275 MWt)	TPP was stopped after 10 days of shelling.	unknown	58

Figure 3. Layout of power supply to the consumers in Donbas.[14]



Specifically, 11 power lines and 88 transformer substations were damaged in the Sloviansk district in June 2014, causing the interruption of power. On June 7, 2014, the Luhansk transformer substation that ensured power supply to Luhansk airport was hit [59]. At that time, Luhansk airport was a base for Ukrainian forces [60]. On June 17, 2014, a transformer substation in Mariupol was struck, cutting the power supply to a TV station and tower [61].

Similar events occurred in all combat zones. In particular, there were large interruptions of power in Donetsk and Luhansk [62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73]. There were other cases of sabotage and discovered preparations for the destruction of power lines and TPPs [74, 75].

During the first year of warfare, over 1,000 power outages were reported in just the Donetsk region due to damage to 35-110 kV power lines. Over 10,000 incidents were in 6-10 kV lines and transformer substations [76]. In the Donetsk and Luhansk regions together, as of January 7, 2015, there were 55 towns that were de-energised (partially or completely); 28 transmission lines 220-330 kV were disabled, as were 3 transformer substations 220-330 kV; 44 lines 110-150 kV, 20

[14] Some explanation of the figure 4:

Luhansk TPP Island – the territory that disconnected (physically) and works autonomously with a single source of energy supply (Luhansk TPP).

Russian-backed Island – the territory that virtually disconnected from the energy system of Ukraine and is supplied from Russia through the "Shakhty-Peremogha" line (Peremogh substation). Ukraine does not have operational control over the flow of energy.

Ukrainian-backed Island – the territory that operates synchronously with the system of Ukraine and under its operational control. Distribution of energy and payment collection are, however, under the control of separatists. The main part of the electricity supply to the occupied territory comes from the Starobeshivska and Zuivska TPPs (also seized by separatists). Some supply comes from Ukraine.

Figure 4. The situation in Donbas (December 31, 2016).

substations 110 kV; 86 lines 35 kV, 31 substations 35 kV; 149 lines 6-10 kV, 780 substations. In total, as of January 1, 2015, the cost to the electricity network, by preliminary estimates of the Ministry of Energy, had exceeded 3.92 billion UAH.

Damage to the electric power infrastructure were also recorded by the OSCE Special Monitoring Mission to Ukraine (refer to Fig. 4 and Appendix 6).

Mine workers health and safety was compromised due to electrical power outages caused by damaged transformer substations and power lines which recurred in 2016-2017 [77, 78, 79, 80, 81, 82, 83, 84, 85, 86]. These power disruptions exposed the dependency of water pumping and filtration plants, threatening civilian access to clean water [87, 88, 89, 90, 91, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103].

Additionally, loss of heating pumps due to power outages in the winter season could have resulted in a humanitarian disaster, like in Avdiivka in late January – early February 2017, when the temperatures reached -20 °C [104, 105]. Rebel shelling caused damage to power lines. The city along with the coke and chemical plant found themselves without water and electricity [106, 107, 108, 109, 110, 111, 112]. The situation was resolved by the plant implementing an emergency plan and establishing emergency sources of electricity, which ensured heating for the city [113, 114]. Additional damage to the infrastructure was also recorded by the OSCE SMM [115, 116].

It must be noted that first, the loss of power exposed the dependencies of other sectors of critical infrastructure such as the water supply system for their safe and reliable functioning. In addition, the power outages affected all the people in the zone of combat indiscriminately, which means that Russia's hybrid warfare in Donbas caused as much suffering to its own supporters as to those who continue to support Ukraine's government.

3.4. ATTACKS ON INTERNATIONAL GAS TRANSIT ROUTES

The gas transit system (GTS) of Ukraine supplies natural gas to Ukrainian consumers and its further transit to Europe. The GTS was attacked from the start. In May and June 2014, three explosions occurred in Urengoy-Pomary-Uzhgorod high pressure gas pipeline in the Ivano-Frankivsk region [117, 118, 119]. On June 17, 2014 an explosion occurred in the same pipeline in Poltava region [120, 121, 122, 123].

In these cases, there were just minor problems for the GTS which was able to repair the damaged pipelines. Transit of Russian gas to EU was not put at risk as the damage was not extensive enough. [124].

The attacks were made by setting explosive devices under a gas pipeline and before international negotiations on the reliability of natural gas supply from Russia to the EU, which were held with the participation of Ukraine, Russia and the EU [125]. Simultaneously, Russia's activities in the EU information space intensified promoting the idea of Ukraine's unreliability as a natural gas transiter to Europe and the need to construct gas transit corridors bypassing Ukraine.

However, transit of gas was not stopped due to Ukraine's extensive pipeline system, existence of reserve pipelines and alternative routes. This infrastructure represents significant resilience of the Ukrainian GTS.

3.5. DAMAGE TO INTERNAL GAS DISTRIBUTION PIPELINES

Repeated attacks on the gas distribution infrastructure took place, including the seizure of compressor plants and destruction of gas pipelines. This stopped gas supply to consumers, housing and utility facilities as well as thermal

Figure 5. Points of explosions in the Urengoy-Pomary-Uzhgorod gas pipeline in 2014.[15]

[15] http://ua.korrespondent.net/ukraine/politics/3380167-vybukh-na-hazoprovodi-u-poltavskii-oblasti-dyversiia-chy-stara-truba

power plants. Having established control over the gas pipelines in Donbas, rebels blocked gas supplies to northern districts of the Luhansk and Donetsk regions, which were under the control of Ukraine [126].

There are certain instability zones in the internal gas distribution network of Ukraine, which became apparent as a consequence of the conflict in the eastern part of the country. One gas distribution node close to the combat zone is responsible for the distribution of natural gas along the Petrovsk-Novopskov, Orenburg-Novopskov, Urengoy-Novopskov, Ostrogozhsk-Sheblinka and Yelets-Kremenchuk-Kryvyi Rih lines. This key node ensures connects different gas networks.

A critical gas distribution node in the western part of Ukraine that represents the end points of the Khust-Satu Mare, Uzhhorod-Beregovo, Sokhranovka-Uzhgorod and Sudzha-Uzhgorod lines is responsible for shipping natural gas to the EU. Those two nodes play an important role in ensuring the stability of natural gas supply inside Ukraine and transit beyond it. However, as the nodes lie outside the conflict zones, the risk introduced by the conflict in Donbas to the critical nodes of the Ukrainian gas transportation system is manageable (Authuska-Sikorski; 2014).

The main gas pipeline Kramatorsk-Donetsk-Mariupol[16] was damaged by mortar rounds near Ocheretino (north-west of Donetsk) on June 12, 2015 [127, 128, 129]. The gas pipeline lies beneath the ground and the mortar hits caused this segment of the pipeline to close. [130, 131].

Since this segment had no alternative gas supply routes, Mariupol, Berdiansk and nearby cities were denied gas service[17]. Some large consumers in the region, for instance steel plants in Mariupol and municipal energy companies in the region, were forced to cut their gas consumption and, therefore, their productive capacity. Hence, the economy was left without revenue and people obtained limited services. Repair works took 2 days [132].

Gas infrastructure was also damaged in other population centers within Donbas [133, 134, 135, 136, 137, 138, 139, 140]. The OSCE Special Monitoring Mission to Ukraine also recorded damage to gas infrastructure, as detailed in Table 2 below.

Deliberate attempts to cut off gas supply were also undertaken [153, 154]. Preparations for sabotage in other areas were also recorded by the OSCE SMM [155]. Nevertheless, because of the

Table 2. Damage to gas infrastructure, as recorded by the OSCE SMM

Date of attack	Location	Details of the impact	Possible attacker	Link
22.09.2014	Talakivka (20 km north-west of Mariupol)	At least eight houses and two gas pipelines were seriously damaged.	Had been shelled from the north-east direction; twelve shell craters were observed in the vicinity of the checkpoint (*"DPR"-controlled*).	141
02.2015	Trokhizbenka (40 km west of Luhansk)	The SMM saw severe damage to village infrastructure, including water and gas lines.	-	142
12.05.2015	Town of Stanytsia Luhanska	Several houses and a gas pipeline were damaged by the attacks of 12 May.	Armed members of the "LPR" attacked the town of Stanytsia Luhanska and the bridge with anti-tank guided missile (ATGM) and rocket propelled grenades (RPG).	143

[16] Gas pipeline Kramatorsk-Donetsk-Mariupol is a high pressure main pipeline DN 1000 (diameter 1000 mm).

[17] У Маріуполі лишилось газу на кілька годин, "Азовсталь" і ММК – без газу. http://www.pravda.com.ua/news/2015/06/12/7071057/?attempt=1 МАРІУПОЛЬ, БЕРДЯНСЬК І ВОЛНОВАХА НА КІЛЬКА ДІБ ЗАЛИШИЛИСЯ БЕЗ ГАЗУ https://104.ua/ua/news/id/mariupol-berdjansk-i-volnovaha-na-kilka-dib-zalish-12616 Поставки газа в Мариуполь и Бердянск только что восстановлены – Яценюк. https://economics.unian.net/energetics/1089224-postavki-gaza-v-mariupol-i-berdyansk-tolko-chto-vosstanovlenyi-yatsenyuk.html

Date of attack	Location	Details of the impact	Possible attacker	Link
12.06.2015	Novokalynove (35 km north-west of Donetsk)	Shelling of a gas pipeline.	The SMM examined two craters assessed to have been caused by shells (122mm or larger) fired from 150 degrees in a south-south-easterly direction (*"DPR"-controlled*).	144
07.07.2015	Telmanove	Shrapnel damaging an overhead gas pipeline.	The SMM assessed that the damage was caused by 152mm artillery shells fired from the west-south-west.	145
29-30.07.2015	Dzershinsk (54 km north of Donetsk)	The SMM observed 12 impacts caused by mortar and artillery and conducted crater analysis at two locations. Telephone, electricity and gas infrastructure had also been affected.	The SMM assessed the direction of fire to have been from an east-south-east direction (*"DLPR"-controlled*).	146
05.08.2015	Luhanske (57 km north-east of Donetsk)	The SMM observed shrapnel damage to three houses and saw a crater near a gas line.	-	147
21.08.2015	Lebedynske (16 km north-east of Mariupol)	Electricity line and gas pipeline were damaged.	The SMM observed six fresh craters and assessed that five of them were caused by 82mm mortar shells fired from a south-easterly direction, while the sixth was caused by a calibre above 120mm originated from the same direction (*"DPR"-controlled*).	148
24.08.2015	Svitlychne, the south-eastern part of government-controlled Nizhniy (56 km north-west of Luhansk)	The SMM noted that a gas pipeline was heavily damaged and electric cables were cut.	The SMM observed two fresh impacts and carried out crater analysis, concluding that they had been caused by fire from a southerly direction. The type of weapon used was assessed to be 122mm Grad multiple launch rocket systems (MLRS) rockets (*"DLPR"-controlled*)	149
18-19.10.2016	Vynohradne (10 km east of Mariupol)	The SMM noted damage to civilian infrastructure, including severed gas pipelines and power lines.	The SMM saw five impacts, assessed as caused by 122mm artillery shells, fired from an easterly direction (*"DPR"-controlled*).	150
22.10.2016	Talakivka (90 km south of Donetsk)	There was damage to the main gas pipeline and two civilian houses. The gas pipeline had large shrapnel holes. The SMM observed shrapnel damage to a nearby gas pipeline and the house and noted that wires of a nearby electrical pylon were severed.	The SMM assessed that all three craters were caused by 122mm artillery round impacts fired from an east-south-easterly direction (*"DPR"-controlled*).	151
02.11.2016	Vynohradne (10 km east of Mariupol)	The SMM observed shrapnel damage to a gas pipeline and the walls and roofs of several houses, downed electricity lines and broken windows.	The SMM observed six fresh impact sites, all assessed as caused by artillery rounds fired from a north-easterly direction (*"DPR"-controlled*).	152

local nature of the infrastructure and the small scope of attacks, the actions described above represent minor (easily recoverable) attacks on critical energy infrastructure.

3.6. BLOCKING OF COAL SUPPLIES AND DESTRUCTION OF TRANSPORT INFRA-STRUCTURE

For the entire duration of the military operations in Donbas, blocking and destruction of coal transportation routes to Ukrainian TPPs was repeatedly observed (damage to bridges, railway lines, rolling stock, electrical equipment – see Table 3 on the following page) [156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 170, 171]. It was also reported that the separatists were preparing explosive demolition of railways and bridges in other regions of Ukraine [172, 173, 174, 175, 176]. However, it is likely that the disruption of transport infrastructure used for coal had other goals extending to the transport needs of both civilian and military.

Table 3. Damage to transport infrastructure, as recorded by the OSCE SMM

Date of attack	Location	Details of the impact	Possible attacker	Link
15.02.2015	Zelenyi Kolodez (29 km south-east of Kharkiv)	An electrician on duty informed the SMM that at 01:07 hrs he heard an explosion and the substation began to malfunction. Two transformers were damaged. Representatives of the railway police, Security Service of Ukraine (SBU) and the prosecutor's office are preliminarily investigating the incident as intentional damage to property (enshrined in Article 194 of the Criminal Code of Ukraine).	unknown	177
25.03.2015	Mezhova (127 km south-east of Dnepropetrovsk).	An explosive device was detonated as a train transporting coal from Donetsk region to Dnepropetrovsk region was passing. The explosion damaged one train car and three railway sleepers, but the train was not derailed. The police chief said that 2 kg of TNT were used.	unknown	178
18.08.2015	Nyzhnoteple (25 km north of Luhansk)	In government-controlled Nyzhnoteple, railway tracks were blown up while a train was travelling to Shchastia. According to the interlocutor, the train consisted of 45 wagons transporting coal from an "LPR"-controlled area to the Shchastia power plant. The last two wagons and 20 m of railway track were destroyed. The incident site is a mined area located around 1 km from the contact line.	unknown	179

As a consequence of destroyed railways and coal mines[18], Ukraine experienced in 2014 a severe shortage of anthracite coal used by its thermal power plants. Ukraine was thus forced to import coal, mostly from Russia as this was the easiest option in terms of logistics and time[19]. However, Russia sometimes blocked exports of coal to Ukraine, presumably to weaken support for the government in Kiev. For example, Russian Railways blocked a shipment of approximately 1,000 wagons of coal at the border in late November 2014 [180, 181, 182, 183, 184, 185, 186].

At the same time, according to the Federal Cus-

[18] About half of Ukrainian thermal power plants use anthracite for their operation. This coal is mined only in Ukraine (in Donbas), Russia, China, Vietnam, North Korea, Australia and South Africa. There are small reserves of anthracite in the USA and Poland.

[19] According to the State Fiscal Service, the cost of coal imported to Ukraine in 2014 was USD 1.773 billion, incl. USD 1.138 billion from Russia. Refer to: http://economics.unian.ua/energetics/1031951-ukrajina-u-2014-rotsi-importuvala-vugillya-na-18-mlrd.html

toms Service of the Russian Federation and Russian Railways, over 1.3 million tons of anthracite was exported to Russia from the occupied areas of Donbas in 2015. The coal was partially returned to Ukraine and even exported to Europe, but as coal of Russian origin [187, 188, 189]. The OSCE SMM has also recorded the export of coal to Russia [190, 191, 192, 193, 194, 195, 196, 197, 198, 199].

The shortage of anthracite coal, which is mostly mined in the occupied areas of Donbas, threatened to stop half of Ukraine's thermal power plants and some municipal boilers, thus potentially endangering the stability of the energy supply throughout the country. Ukraine was forced to impose a temporary state of emergency in its electricity market, which limited the operation of industry and the supply of electricity to consumers [200, 201, 202] .[20]

The disruption of the coal supply pressured Ukraine during negotiations with self-proclaimed authorities in certain areas of the Donetsk and Luhansk regions. It also led to the creation of non-transparent transactions of coal supply from the territory. [203, 204, 205, 206].

In March 2017 Ukrainian security services arrested dozens of armed Ukrainian activitists who had blocked the railway connection between government-held and separatist-controlled territories at Kryvyi Torets train station in the Donetsk region. The activists blocked the railway in order to stop the coal trade, which they claimed was helping to fund rebel activities in the region. Consequently, on March 14, Russian state media confirmed that the self-proclaimed Donetsk People's Republic started exporting coal to Russia. One day later President Petro Poroshenko announced a complete trade blockade after the separatists seized important industries in response to the rail blockade. The trade blockade was supposed to last until the seized industries are given back to Ukrainian authorities, however, it is likely that the blockade will strengthen separatist tendencies, raise tensions and undermine the Minsk Peace Process.

Since anthracite coal was at that time the primary fuel for about a half of Ukraine's thermal power plants, the interruption in its supplies can be classified as an attack on critical energy infrastructure. Ukraine however, was able to overcome the shortages and its thermal power plants resumed service.

3.7. BLOCKING OF INFRASTRUCTURE RECOVERY WORKS

Works for the recovery of power lines, water supply systems, electricity supply to water filtration plants and gas infrastructure were blocked or disrupted by rebels (refer to Appendix 7). During periods of intensive fighting, rebels repeatedly attacked water canals and pumping stations that were ensuring water supply, as well as power lines. The rebels then fired on repair teams [207, 208, 209, 210]. As a result, some villages in the Donetsk region were left without water and power supply for several weeks.

In June 2015, residents of the towns of Krasnogorovka and Marinka in the Donetsk region lived without electricity and had problems with water supply for more than two weeks due to inoperative pumps. By firing at electricians, snipers from the "DPR" did not allow them to make repairs [211, 212]. Ten staff members of Donetskoblenerho, an electricity distribution system operator, died and 16 were wounded during repairs in the period between June 2014 and June 2015 [213].

Repair work on power lines from Luhansk TPP, water supply systems near the town of Popasna and electricity supply to water filtration plants was also blocked. Approaches to power lines and water pipes were blocked with mines [214, 215]. Recovery of gas infrastructure also stopped due to rebel gunfire [216]. Specifically, teams engaged in restoring gas supply to Marinka and Krasnogorovka were also subject to shelling in 2016 [217, 218, 219, 220, 221].

Obstruction of repair operations re-occurred in 2016 [222, 223, 224, 225] and in 2017. For example, in February 2017, repairmen could not restore power supply to the city of Avdiivka and

[20] On April 07, 2015, the Law of Ukraine "On Electric Power Industry" was amended with regard to regulation of relations in the area of electric power industry within ATO area. Refer to: http://zakon4.rada.gov.ua/laws/show/284-19 To ensure its implementation, the CMU adopted resolution No. 263 on May 07, 2015. Refer to: http://zakon2.rada.gov.ua/laws/show/263-2015-%D0%BF

to the local coke and chemical plants because of shelling and fire from light weapons. The city was without heat for more than a week [226, 227, 228, 229, 230, 231]. Some cases of prohibiting access for the repair teams, accompanied by the OSCE SMM, were recorded [232, 233].

The above actions caused a local increase in social and political tensions and a reduction in the level of support to the units of the Ukrainian armed forces from the local population.

3.8. INFORMATION CAMPAIGN AROUND THE DELIVERY OF 'HUMANITARIAN AID' TO THE POPULATION OF UKRAINE

Supplies of natural gas and electricity from Russia to the occupied territories of Donbas were accompanied by an extensive Russian information campaign. One such case involved gas supply to Genichesk city (Kherson region) in the winter of 2015-2016. The mayor of Genichesk sent a message to Vladimir Putin with a request for help (later the mayor denied he had sent such a message). In response, Putin on television instructed the authorities of Crimea to ensure supplies for the city's population. The gas was supplied, but it was Ukrainian gas from the Strilkovske deposit, which was mined in the Genichesk district and had been previously pumped into a storage site in Crimea [234, 235, 236, 237, 238, 239, 240, 241].

A similar case was observed in 2016. While advertising 'humanitarian' supplies of gas, Russia was still issuing bills for the gas to Ukraine. According to Russian assessments, the cost of gas that had been supplied to the Donbas areas not controlled by Ukraine amounted to USD $670 million as of May 2016.[21]

In the meantime, Ukraine cannot objectively account for gas supplied, nor its use, due to the lack of control both on the border with Russia and in the Donbas areas not controlled by Ukraine [242, 243]. Consequently, Naftogaz of Ukraine has refused to pay for the gas [244, 245].

Another similar situation was observed with respect to electricity supplies. Self-proclaimed authorities in the occupied areas stopped making payments for the consumed electricity and by May of 2015 the debt to Ukraine for the consumed electricity and natural gas exceeded USD $1 billion [246].

Another example is Ukraine's termination of water and electricity supply to the annexed Crimea. Criticism of this decision by some pro-Russian Ukrainian politicians [247, 248], officials of the Russian Ministry of Foreign Affairs and the President of Russia [249, 250] should be considered as linked elements of a consolidated campaign by Russia.

Although information campaigns are a component of hybrid warfare, the events described above did not directly involve critical energy infrastructure. Supplies of electricity, gas and water can become a critical issue for a population deprived of them, but in these limited instances the supply was maintained or interrupted only for a limited period of time.

3.9. CYBER ATTACKS ON THE CONTROL SYSTEMS OF ENERGY FACILITIES

Since 2008 we have seen a steady progression in the severity and scale of cyber-attacks on critical infrastructure. In 2008 cyber-attacks coincided with a traditional military operation for the first time in the Russian-Georgian War.[22] In 2010 Stuxnet malware was placed at a nuclear enrichment facility in Iran which targeted ICS and denied operators the view and control of equipment used in a critical process resulting in physical damage.[23] Malware erased data on 30,000

[21] In May 2016, Russia's Gazprom actually demanded that payment. However, the supplies were carried out in violation of the terms and conditions of the existing contract between Gazprom and Naftogaz of Ukraine. Naftogaz has not accepted gas from Gazprom on entry points to the Ukrainian gas transportation system and has no intention to pay for it.

[22] Danchev, D., Coordinated Russia vs Georgia cyber attack in progress, http://www.zdnet.com/article/coordinated-russia-vs-georgia-cyber-attack-in-progress/ August 11, 2008

[23] Langner, R., To Kill a Centrifuge, http://www.langner.com/en/wp-content/uploads/2013/11/To-kill-a-centrifuge.pdf

[24] Rashid, F., Inside The Aftermath Of The Saudi Aramco Breach, Dark Reading, 8/8/2015, http://www.darkreading.com/attacks-breaches/inside-the-aftermath-of-the-saudi-aramco-breach/d/d-id/1321676

[25] Alert (ICS-ALERT-14-281-01E) Ongoing Sophisticated Malware Campaign Compromising ICS (Update E) US ICS-CERT https://ics-cert.us-cert.gov/alerts/ICS-ALERT-14-281-01B , Original release date: December 10, 2014

computers belonging to one of the world's largest energy companies in 2012.[24] Since 2011[25] malware has been found searching the Internet for locations of particular brands of industrial control equipment.[26] In 2014 the control systems of a German steel mill were compromised denying view and control of equipment which also resulted in physical damage.[27] Cyber-attacks on critical infrastructure have also become associated with political and even military conflict. The cyber-attack on Ukraine's power grid just before Christmas in 2015 also occurred in the same context of political-military conflict over Russia's illegal annexation of the Ukrainian province of Crimea. Even of greater concern is that these cyber incidents are suspected to have been caused not by cyber criminals or student hackers but by state supported advanced and persistent threat (APT) actors [366].

According to officially published reports,[28] a successful cyber attack against energy infrastructure was executed in December 2015 against several regional power distribution networks in Ukraine.

The blackout occurred in Ivano-Frankivsk, Chernivtsi and Kyiv regions on December 23, 2015 at about 4:30 p.m. A message [251] about large-scale failures in the power supply system that occurred for unknown reasons appeared on the web-site of "Prykarpattiaoblenergo" (Ivano-Frankivsk region). Soon it was determined that the cause of telecontrol equipment failures was an external intrusion into the operation of the power grid monitoring and control systems. A company representative also highlighted that a sudden increase in the volume of consumer calls caused technical failures in call center operations. He then noted that the company disabled its telecontrol equipment and that maintenance teams were restoring the power supply manually, i.e. driving to hot spots and manually reconnecting the substations [252].

In the largely rural Ivano-Frankivsk region ("Prykarpattiaoblenergo") the attack resulted in the de-energisation of 27 substations of 35-110 kV. The power supply was fully stopped in 103 population centers and partially interrupted in 186 ones [270]. Up to 30 substations were off (7 PS-110 kV and 23 PS-35 kV) and, depending on how subscribers are counted, the blackout affected from 80,000 to 250,000 people who found themselves without power supply [251] in the Kyiv region ("Kyivoblenergo"). In total, the interrupted power supply lasted between 1 and 3.5 hours

On December 28, 2015, SSU stated it had found malicious software in the networks of some regional energy companies and ensured its localisation [252].

The first event analysis that was carried out by both Ukrainian and foreign experts in January 2016 verified the execution of a targeted cyber attack against Ukrainian electric power facilities [255, 256, 257, 258, 259, 260, 261, 262].

In January 2016, preparations for other cyber attacks were disclosed through a detailed inspection of other critical infrastructure facilities. At that time, cyber attacks were targeted at the facilities of NEC "Ukrenergo", a system operator of the Unified Energy System of Ukraine [263] and Kyiv International Airport "Boryspil" [264].

A special case investigation group of the Ministry of Energy and Coal Industry of Ukraine has confirmed an unauthorised interference into the power grid operations [265], having noted that the intrusion was from the Internet sector that belonged to providers in the Russian Federation.

[26] Sandworm and SCADA, Trend Micro http://blog.trendmicro.com/sandworm-and-scada/ October 16, 2014

[27] The State of IT Security in Germany 2014, Federal IT Department (BSI) Germany. p. 31. https://www.bsi.bund.de/SharedDocs/Downloads/EN/BSI/Publications/Securitysituation/IT-Security-Situation-in-Germany-2014.pdf?__blob=publicationFile&v=3

[28] US DHS ICS-CERT Alert https://ics-cert.us-cert.gov/alerts/IR-ALERT-H-16-056-01 and SANS/E-ISAC joint report https://ics.sans.org/media/E-ISAC_SANS_Ukraine_DUC_5.pdf

[29] "Prykarpattiaoblenergo" representatives stated: "After a detailed analysis it turned out that control systems of our company were damaged by a malware, which was received through a task-oriented e-mail newsletter to the e-mails of our company. These were common e-mails received from electronic address info@rada.gov.ua. The letters' subject was "Decree of the President of Ukraine No.15/2015 "On limited mobilisation" dated 01/14/2015". "The letters have not caused a single suspicion", - the company said. "The mailing was on March 24, 2015 and the malware was activated during the hacker attack on December 23, 2015. The message was sent to 22 addresses in total. We advise our energy colleagues take seriously the possibility of cyber attacks on energy companies in the future, work on cyber security and involve qualified consultants".

The investigations results [266, 267] that the preparations for the cyber attacks were carried out for at least six months.[29] It was also proven that more than one person took part in the cyber attack, since the intruders' actions were coordinated and simultaneously focused on the information and industrial control infrastructure of the three energy suppliers "Prykarpattiaoblenergo", "Chernivtsioblenergo" and "Kyivoblenergo". One of the power companies also stated that intruders connected to its information networks from Internet subnets that belonged to providers in the Russian Federation.

Generally, the 23 December 2015 cyber attacks consisted of the following notable characteristics [258, 266, 268, 366]:

- adversay's use of social engineering methods (malware hidden in emails) to target employees and gain a foothold on the network;
- once a prescence on the network was established the placement of BlackEnergy malware exploitation tool for reconnaissance and priveledge escalation; ;
- obtaining necessary credentials to access the industrial control network ;
- Took control of operators workstations and proceeded to remotely open breakers at targeted substations effectively stopping the flow of power to customers;
- Overwrote Serial to Ethernet modems used for communication between SCADA and substations with malicious firmware effectively "bricking" the devices, resulting in operator loss of view and control of grid operations;
- Killdisk/wiper software used to delete data stored on workstations and SCADA, forcing operator to switch to manual control (send technicians out to the affeceted substations to manually close the breakers and re-establish power);
- "Denial of Service" (DOS) style attack executed against the call center's capability to accept customer calls wishing to complain about the lost service;

This first cyber attack on Ukraine's energy infrastructure in December 2015 was seen by researchers as a "straight-forward disruptiong event with an emphasis on manual interaction with control systems to induce an outage, and then deploying follow-on malware and actions to delay recovery.[30]

It is important to note that the threat of cyber attacks against the Ukrainian energy system did not disappear but, on the contrary, was repeated in December the following year when a much larger 200 megawatt electricity artery was briefly closed [367]. The "North" substation, a much larger of 330 kV (NEC "Ukrenergo") was completely de-energised on December 17, 2016, which resulted in the outage of a load of 144.9 MW for "Kyivenergo" Public Company (Kyiv city) and of 58 MW for "Kyivoblenergo" (the Kyiv region). A Kyiv pump-storage plant was also de-energised with a loss of in-house supply [ ]. According to a source close to Kyivenergo, who does not want to be named, there was a short time blackout (up to 10 minutes) in northern part of Kyiv region and one district in Kyiv.

This second attack although not causing the dramatic Christmas Holiday outage of the year before did raise concern among industrial control system security practitioners. This time there was a new attack platform discovered with far more reaching capabilities called Industroyer[31]/ Crashoverride. Investigations into the code revealed attempts to neutralise electrical relays. It must be recalled that after the first attack when remote monitoring and control was lost the operator went to manual control of the system. This in part included technicians going out to the affected substations and manually closing the breakers. By neutralising relays the ability for the operator to fall back on manual control to restore power after a cyber induced blackout can become quite dangerous. Without the relays to

[30] Slowik, J., Stuxnet to CRASHOVERRIDE to TRISIS: Evaluating the History and Future of Integrity-Based Attacks on Industrial Environments, Dragos, Inc., p.6., October 30, 2019

[31] Cherepanov, A., Lipovsky, Industroyer: Biggest threat to industrial control systems since Stuxnet, https://www.welivesecurity.com/2017/06/12/industroyer-biggest-threat-industrial-control-systems-since-stuxnet/ ESET, 12 Jun 2017

protect the system any imbalance in the load can cause physical damage to the bulk power equipment [368].

In these two cyber attacks we see in addition to demonstrations of intention and capability, an increasing disregard for the consequences. We also see improvements in capability from "laboratory" style experimentation (returning with more sophisticated cyber attack in 2016) and shifting toward targets (safety relays in an electric grid) that can result in more serious physical outcomes in terms of lost lives, damaged property and harm to the environment.[32] The execution of the attacks required a coordinated and advanced approach that achieved compromise of engineering systems resulting in a loss of operator view and control.

It must be noted that the attackers who directed malicious cyber operations at Ukraine's energy infrastructure achieved their objectives: disrupt supply of electrical power to customers and make it difficult for the operator to recover. In other words they proved that "we can turn your lights off". It is also evident from an analysis of the attack platforms used that the perpetrators were capable of causing costly, long term physical damage to bulk power equipment if they wanted to.

In the future, during times of conflict, in addition to traditional kinetic attacks, NATO Alliance states should be prepared for cyber-attacks directed at infrastructures critical to national economy, national security and well-being of society.

3.10. CRIMINAL PLUNDERING OF ENERGY INFRASTRUCTURE

Repeated looting incidents against energy infrastructure were observed in Donbas. Acting under the shelter of local authorities, criminal groups broke down equipment and sold it as scrap materials.

For example, power supply to Troitske village in the Luhansk region was interrupted in June 2015 due to fighting. Restoration of the power supply was impossible because the transformers were turned into scrap by the locals [270]. There were repeated reports about dismantling of power lines for scrap near the cities of Donetsk, Horlivka, Luhansk and Stakhanov, which constitutes a criminal dimension of warfare [271272, 273].

Military personnel of the so-called DPR-LPR were also involved in the infrastructure looting. The cases were recorded in Donetsk, Luhansk, Toretsk and in other cities of Donbas [274, 275, 276, 277, 278, 279]. Dismantling of equipment at industrial plants and its delivery to Russia as well as the scrapping of energy infrastructure became a very common and lucrative business on the occupied territory [280, 281, 282, 284, 286, 287].

3.11. ATTACKS ON OIL INFRASTRUCTURE

The Ukrainian oil infrastructure remained largely unaffected by the armed conflict. According to official reports, only the Lisichanks refinery in the Luhansk region, owned by the Russian state oil company Rosneft, was damaged after heavy shelling by the Ukrainian army from multiple rocket launcher systems on July 18, 2014, after which the refinery was set on fire. No oil was spilled as the plant was already out of operation. Rosneft soon after demanded compensation from Kyiv for the damage.

A major implication of the conflict are new diversification measures implemented by Ukrainian companies to reduce or even completely terminate dependency on Russian oil imports. An example of this strategy is the Ukrtatnafta-operated Kremenchug refinery, which is now supplied by Azerbaijan's Socar with 1.3 million tons per year. This shows, surprisingly, a positive result of the conflict – Ukraine is diversifying its oil imports and thus strengthening its energy security.

4. SECURITY ARRANGEMENTS TO ENSURE RESILIENCE OF ENERGY SECTOR UNDER CONDITIONS OF CONFLICT

The analysis here reveals that the challenges of hybrid warfare for critical energy infrastructure are limited:

[32] Video footage of what power equipment experiencing damage is like can be seen on the web: https://www.youtube.com/watch?v=oFkfd31Wpng

- where physical destruction of critical energy infrastructure occurred, it was limited in scope and duration; furthermore, most such attacks were kinetic, thus falling more within traditional, rather than hybrid, warfare;
- use of non-identified persons (saboteurs and seditious groups, criminal groups) for the blocking of facilities (damage of equipment, displacement of personnel, psychological pressure on staff) mostly affected infrastructure that was not critical, with the exception of anthracite coal supplies;
- capture of infrastructure, including by criminal groups to gain access to resources, dismantling and sale, only involved non-critical assets;
- blocking of infrastructure restoration by targeted attacks against repair teams and transportation routes did not involve critical enegy assets;
- cyber attacks against energy infrastructure had a significantly lower impact than a kinetic attack would have had.

As modern societies dependent on stable energy supplies, a degradation or destruction of the supporting energy infrastructure will put at risk the national economy, national security and well-being of citizens. Therefore, intentional disruption, degredation or destruction of energy infrastructure and disturbance of energy supply should be considered as a new 'energy dimension' of warfare and taken into consideration for defense policy.

The following means of warfare can be identified (please see Table 4 on the next page): (1) causing psychological pressure in order to spread panic, social tension and discontent with government; (2) causing economic losses due to seizures of CEI and energy resources, thus imposing additional economic burden on the country or getting additional resources for war; (3) obtaining local advantages by achieving a better position to pursue certain operations (combat collision, terms of contracts, ceasefire negotiation) or by forcing the government to do certain actions (payments, sale or purchase of resources); (4) creation of a desired image in the international community through information campaigns in the mass media ('cruelty' of Ukraine in blocking energy and water supply, 'humanitarian aid of Russia' in the form of energy supplies to Ukrainian consumers); and use of malicious cyber tools as an effective, cheap and deniable means that will contribute to the adversaries achievement of its objectives.

The analysis demonstrates that the existing security and protection systems of Ukraine, especially at the beginning of the war were unprepared to deal with the challenges of new hybrid methods of warfare.

However, in reality Ukraine faced terrorist style threats to the safety, reliability and performance of its energy infrastructure by the malicious actions of unidentified groups of people equipped with heavy weaponry (artillery and rockets). The destruction of the infrastructure was not the final goal of attacks. The purpose was to achieve the larger goals of economic and political weakening of the country and the formation of a predisposition to surrender to the aggressor. However, these attempts failed.

New measures aimed at reducing the number of possible threats and increasing the capabilities for crisis response are needed. This should be achieved after a risk assessment process which identifies the nation's critical energy infrastructure, potential traditional and new hybrids threats to their safety, reliability and performace.

The first set of measures could, in some cases, be implemented within the existing emergency response system designed for peacetime as crisis response or disaster recovery plans.[33]

Protection against targeted malicious acts requires a prediction of possible intentional attacks and a capacity to effectively mitigatg them. Government and operators should implement risk evaluation procedures and establish close private-public partnerships.[34] An important aspect of this system is that it requires the exchange of

[33] For the gas sector, the requirements are presented in Regulation (EU) No.994/2010 concerning measures to safeguard security of gas supply. It requires national governments to develop a Preventive Action Plan and an Emergency Plan for gas supplies.

Table 4. Energy tools of warfare in Ukraine, as identified by the authors

Psychological pressure	Economic losses	Tactical benefits	Creation of image
Threat to stop the operation of the Unified Energy System of Ukraine (due to lack of fuel (coal, natural gas) for power generation Stopping power supply (damage to TPP and transformer substations, gas pipelines' disruption) Termination of water supply to cities due to pumping stations breakdowns (damage to electrical networks, pipelines, obstructing repairs) Use of malicious cyber tools as an effective, cheap and deniable means to deny vital services and to intimidate: "we can turn your lights off" anytime we wish"	Seizure of energy production facilities and infrastructure (industry, resources, infrastructure) Payment for stolen resources, goods and services. (Ukraine pays the bills for the energy supply to the occupied territories, while consumers of these areas do not pay.) Seizure of Ukrainian state coal mines and sales of seized coal to Ukraine under the guise of Russian contracts Cost of service disruptions in dependent civilian infrastructures. Cost of repairs and increased cost of manual operations after loss of automated systems and capability for remote management and control	Protection against possible attacks by means of positioning military troops at the facilities that are dangerous to attack (chemical plants or power plants and supply networks, gas pipelines) Getting advantage in military operations (inability to leave the site of defense due to the need to protect the infrastructure facilities, such as power plants, transportation hubs, airports) Getting advantage in the process of political negotiation (ensuring favorable conditions for the contracts to supply electric power to Crimea, the pressure to get better position at peace talks) Disruption of the energy sector just when the adversary does something they know will draw target nation's response.	Influence on international institutions (including the framework of "Normandy" and "Minsk" negotiating groups), politicians and population of Western countries in order to produce an indirect pressure on Ukraine (lobbying for contracts putting Ukraine at a disadvantage - OPAL, Nord Stream 2 pipelines) Formation of an image on the international stage that would be positive for Russia and negative for Ukraine. For these purposes, the following are used: criticism of Ukraine's termination of power supply to Crimea; provision of "humanitarian aid" by Russia; forcing Ukraine to finance the territories that are occupied by Russia Impression given to citizens that their Government is incompetent in insuring their well-being.

sensitive information between stakeholders and the readiness of military and law enforcement personnel to activate additional measures. These activities should be reflected in defense policy.

An analysis of the wartime events related to the operation of Ukrainian energy infrastructure reveals a number of measures that could be useful:

- implement an emergency preparedness plan, i.e. involve law enforcement and armed forces in protecting energy infrastructure according to the established threat levels;
- implement cyber risk evaluation and reduction measures that result in capabilities that will monitor, detect and effectively respond to cyber incidents and unauthorised intrusions of ICS found in critical energy infrastructure;
- increase the awareness of armed forces and law enforcement units about the importance of energy security, including a stable operation of CEI;
- strengthen civil-military cooperation and encourage voluntary support in securing energy supplies to the population;

[34] This planning and risk assessment could be informative and provide a basis for determining who (the government or the private sector/owner/operator of the critical infrastructure) would pay for security and redundant operating systems.

- create reserves of energy resources and generation capacities;
- introduce additional organisational and technical safeguards to protect CEI against accidental damage caused by fighting;
- establish an international monitoring mission to prevent deliberate damage to infrastructure and obstruction of CEI restoration.[35]

5. CONCLUSIONS AND RECOMMENDATIONS

As a result of the analysis of data from public sources about acts against energy infrastructure of Ukraine, including critical assets, the following conclusions can be drawn.

1) Any escalation of the military conflict in the south-east of Ukraine is usually accompanied by damage to the energy infrastructure. This is particularly true for the electricity and gas infrastructure located near the front line. However, accurate assessments as to what share of the damage was caused intentionally as part of military operations requires additional information not available in open sources.

At the same time, numerous cases of intentional traditional kinentic and new cyber-physical impacts on energy infrastructure (mining, shelling of gas pipelines, power plants and transformer substations, power lines, impeding of repairs of the damaged infrastructure by way of shelling and firing at repair teams from small arms) were recorded.

The following should be classed as intentional operations:

- cases of deliberate explosive demolition of transformer substations for military purposes in order to reduce the defense capacity of Ukrainian military units (termination of power supply to a military post of Luhansk airport) and depriving people in large cities of the possibility to receive the signal of Ukrainian TV (stoppage of broadcasting from the Mariupol TV station);
- cases of explosive demolitions on gas pipelines to produce an impact on transit capabilities of Ukraine (explosive demolition on the transit gas pipeline "Urengoy-Pomary-Uzhgorod");
- cases of internal gas distribution pipelines destruction (termination of gas supply to the Vuhlehirska TPP and damage to the pipeline "Kramatorsk-Mariupol" ensuring the supplies to the south of the Donetsk region in the summer of 2015);
- malicious intrusions from cyberspace with physical effect (opening breakers at substations and disrupting flow of electrity to citizens) on the industrial control systems used to remotely montitor and control critical energy infrastructure. The cyber-attacks that took place against a Ukrainian regional power grid in December 2015 and the apparently even more sophisticated follow up attack on the Ukrainian capital nearly a year later is a serious wake-up call for security policy practitioners. These events took place in an increasingly militarized cyberspace environment, with many nations treating it as a new domain for military operations.

2) As a rule, many events involving energy infrastructure were accompanied by information (or rather disinformation) campaigns on the part of Russia[36]. Highlights of the campaigns were a bit different, depending on a target audience (people of Russia, or Ukraine, or European countries and the USA):

- to Western audiences, the promotion of the idea that Ukraine is an unreliable and even dangerous partner, because it could ensure neither safety of its nuclear power, nor reliability

[35] Similar to the OSCE Special Monitoring Mission to Ukraine that facilitated a ceasefire and monitored the process of demining, repair of major water supply pipelines and power lines. The SMM teams were in close contact with the Joint Coordination Center (Ukrainian and Russian representatives), as well as with the Armed Forces of Ukraine and "DPR" "commanders" on site to help maintain the ceasefire.

[36] For more details about numerous mechanisms of the pro-Kremlin disinformation campaign in Europe refer to, for example, features "Agents of the Russian World" on Chatham House website; "Putin's Propaganda Machine" by Marcel van Herpen; "Mechanisms of Influence of the Russian Federation" on European Value website; "The Bear in Sheep's Clothing" on Wilfried Martens Center website and East StratCom Task Force "The Disinformation review" https://euvsdisinfo.eu/

of natural gas transit to Europe; and that at the same time all this imposed a threat of an ecological disaster;

- to Ukrainian and Russian audiences, there was a message that power in Ukraine was seized by a junta that had staged a coup, did not care about the ordinary people and could not ensure their safety, was interested in war and profiting from it;
- simultaneously, a message was being sent that the conflict was a Ukrainian civil war with no involvement from Russia and that it threatened a humanitarian catastrophe on a European scale.
- a message may have also been sent to foreign businesses working in Ukraine that it was not a safe place for investment or conducting operations in the aftermath of the NotPetya malware which begin with targeted the governments accounting software and spreading to major corporations like Maersk Shipping lines resulting in loses of hundreds of millions Euro.[37]

The Russian information, propaganda and cyber campaigns wre actually limited to one central idea: the cessation of support for the current government of Ukraine on the part of both its own citizens and Western countries resulting in a new pro-Russian government. One that would end the war and ensure peace and prosperity for Ukraine. Therefore, the main condition of stabilising the situation was Ukraine's renunciation of European integration and cooperation with NATO [288]. It is clear that after almost four years of trying, Russia's campaigns have not succeed.

3) It is noteworthy that RF actions in Ukraine in 2014-2017 are in complete accord with the so-called "Gerasimov Doctrine" [289, 290]. This is confirmed by both comparative analysis of the "Gerasimov Doctrine" and RF actions which led to annexation of Crimea [291] as well as subsequent events in Ukraine's Donbas.[38]

While the use of special operations forces against Ukrainian people and infrastructure was only developed nearby the front line in Donbas, the use of internal opposition for establishing a permanent front is widespread throughout Ukraine. Of particular importance is the information and propaganda campaign aimed at the formation of protest (against current authorities) and tensions within society, whose forms and methods are being continually improved. Russia's actions have only achieved a military stalemate in Donbas, while they have failed against the Ukrainian population, which is now largely anti-Russian.

4) Additional research is required to provide a more accurate assessment of the impact of energy infrastructure damage on the country's defense capabilities, including the development of appropriate methodology. Ukraine has developed pre-formalisation of the methodology for assessing the impact of deliberate attacks on energy infrastructure from the viewpoint of military component.[39]

5) There is a need to resolve the problems of coordination between different military and civil services. This requires the establishment of an appropriate legal framework that would identify the responsibilities of the relevant state authorities for the protection of critical infrastructure.

6) The involvement of international organisations in building the channels of communication between fighting parties is important and in some cases could help prevent damage to critical infrastructure as well as achieve agreement on ceasefire arrangements in order to repair infrastructure.

The development of an international framework on the protection of critical energy infrastructure from malicious actions is needed, one that is similar to the current international framework for the protection of property from seizure (through international law). One promising initiative for

[37] More on Notpetya is found at Greenberg, A., The Untold Story of NotPetya, the Most Devastating Cyberattack in History, https://www.wired.com/story/notpetya-cyberattack-ukraine-russia-code-crashed-the-world/amp?__twitter_impression=true 08.22.18

[38] The Global Hybrid War: Ukrainian Front. / monograph under the General Editorship of V.Horbulin (in Ukrainian). K.: NISS, 2017. – 496 p.

[39] Sukhodolja O, Bogdanovich V. Formalization of energy threats impact on a state defense capabilities // Information processing systems – 2017. – №1. – p.168-173. (in Ukrainian). http://www.hups.mil.gov.ua/periodic-app/article/17308

addressing cyber threats to critical infrastructure is the proposal by Microsoft for a "Digital Geneva Convention for Cyberspace".[40] Unfortunately for the security of cyberspace the international security policy community has yet to come up with an effective response to advanced persistent threat (APT)[41] actors who freely use cyber means to target critical infrastructure.

In closing we need to recognise that the methods of hybrid war described in this study represent a new sinister trend in conflict. One whose moves and actions are characterised by secrecy, cynicism and the convenience of denial. The domains of conflict have also widened with the addition of malicious activities in cyberspace which threaten the technical foundations of modern economic life, national security and well-being of society. This new form of grey warfare represents a significant challenge to democratic societies based on trust, transparency and respect for the rights of others.

APPENDIX 1. SEIZED ASSETS IN THE ELECTRICITY SECTOR

As a result of the occupation of the territory of Crimea, Ukraine lost control of a significant number of assets in the energy sector, both state and private property. They include the following:

- combined heat and power plants (CHP) including Simferopol, Sevastopol, Kamysh-Burunsky and Saki and heat networks, with installed capacity of 144.5 MW. These assets were owned by JSC "Krymteploelektrotsentral" with 37.23% shares belonging to the State Property Fund of Ukraine;
- wind power plants, mainly state-owned, including the SE "Donuzlavskaya wind power plant", capacity of 11.60 MW; Tarhankut, capacity of 20.05 MW; WEC Vodenerhoremnaladka, capacity of 28.22 MW; East-Crimean wind farm, capacity of 2.81 MW;
- solar power stations, which were recently built by private investors (224.63 MW);
- power lines (transmission and distribution).

A separate division of Crimean ES SE NEC "Ukrenergo" that operated lines with a total length of 1369.4 km and 17 transformer substations of 110-330 kV power 3838.8 MVA. The management of distribution lines with a total length of 31.9 thousand km and 270 transformer substations of 35-110 kV was undertaken by the energy companies PJSC "DTEK Krymenergo", which supplied electricity to 99.5% of consumers in Crimea, and PJSC "East-Crimean Power Company" (the remaining 0.5%). The state, represented by the State Property Fund of Ukraine, owns 25% + 1 shares of PJSC "DTEK Krymenergo" and 53.974% of shares of JSC "East-Crimean Power Company".

APPENDIX 2. SEIZED ASSETS IN THE OIL AND GAS SECTOR

Major state owned assets that were lost include PJSC NJSC "Chornomornaftogas" and JSC "Krymhaz". The National Joint Stock Company "Naftogaz of Ukraine" that owns 100% shares of PJSC NJSC "Chornomornaftogas" lost its main production base in the region:

- coastal industrial base providing marine works and construction of offshore fields, including manufacturing of complex steel structures, platforms, marine pipeline sections etc.;
- specialised port "BlackSea" with ship repair complex plot and underwater engineering works;
- technological fleet consisting of 23 ships, including crane vessels, support vessels, rescue, fire, etc;
- 10 marine platforms and stationary gas producing block-conductors, technological equipment, control and communications systems;
- 4 oil rigs: "Siwash", "Tavrida" and deepwather rigs "Peter Godovanets" and "Independence";
- Crimea transportation system is connected to the gas transportation system of Ukraine, including 1,200 km of main gas pipelines, including 282 km of sea pipelines;
- Glibovskyi underground gas storage with active volume of 1,5 bln cubic metres;
- 45 gas distribution stations.

[40] https://blogs.microsoft.com/on-the-issues/2017/02/14/need-digital-geneva-convention/#sm.000gy0k6y1eb3f6ixgx1zhb0k722b

[41] Activities that are associated with states or those groups they sponsor.

SJSC "Chornomornaftogaz" lost an opportunity to extract natural gas, oil and gas condensate in existing and prospective oil and gas fields.[42] While the production level of oil and gas condensate by this company was low (less than 100 thousand tonnes a year), natural gas production in the Black and Azov Seas reached the level of 1.65 Bcm in 2013.

At the end of 2013 Ukraine had only developed around 4% of its economically and technically available fields. The gradual development of the Black Sea fields was seen as possible way to reduce dependence on gas supplies from Russia, including planned increase in gas production up to 5 Bcm. Overall oil and gas reserves in the Black Sea amount to about 2.3 billion tons of fuel equivalent, or about 2 trillion cubic meters of gas. Potential financial losses to Ukraine caused by Russian capture of assets in both Crimea and the shelf area are estimated to be USD $300 billion [292].

Two offshore drilling units and pipelines along with the on-shore infrastructure that ensured production and supply of gas from offshore fields in the Black Sea (the Odeske gas field)[43] were captured. The gas compressor station, which is pumping gas from a deposit in the Azov Sea shelf area (Strilkove), was also captured in the Kherson region[44] [293, 294, 295, 296, 297, 298, 299].

In Donbas, the insurgents of the so-called Donetsk and Luhansk People's Republics have stolen over 50 state-owned mines, raided military-owned companies and looted foreign and Ukrainian-owned businesses[45]. In March 2017, the most important industries were "nationalised" by the separatists in order to establish "official trading relations" with Russia [300, 301, 302]. The Russian government has also sold the right for the development of oil and gas resources in the disputed Ukrainian shelf in the Black and Azov Sea fields to an unknown company. [303].

The biggest power generating plants seized in the occupied territories of Donbas were the Starobeshivska TPP (1.9 GW) and the Zuevskaya TPP (1.2 GW). However, in reality, the number of generating plants in the Ukrainian "temporarily uncontrolled territory" is greater and includes both industrial and municipal power generating capacity[46].

A lack of adequate energy reserves coupled with the seizure of production facilities resulted in significant impacts to the State's ability to ensure uninterrupted critical governmental services (e.g. preparedness, capacity to restore the main energy systems), national and military security and technological and ecological safety in occupied and adjacent territories.

APPENDIX 3. SEIZED COAL MINES IN DONETSK AND LUHANSK REGIONS

Having lost control of some areas in Donbas, Ukraine also lost control over power stations, coal mines, coal enrichment factories and a lot of other enterprises [304, 305, 306, 307][47] . Today, nearly half of Ukrainian coal and practically all of the nation's anthracite coal are being mined on the relatively small occupied territory.

[42] According to a valuation by the Ukrainian Ministry of Environment and Natural Resources, Russia seized an estimated 127 billion hryvna ($10 billion) of assets in Crimea, which included both natural resources and business assets (http://www.pravda.com.ua/news/2014/04/7/7021631/).

[43] Odessa field: inventories of gas in the Odessa and Bezimennoe deposits (opened in 1988) account for 22 billion cubic metres. They are located at a distance of 155 km to the west of the Crimean coast (and 100 km to Ukrainian mainland terotory) at a depth of 30-60 m. Gas production in the fields began in 2012 and by 2015 was supposed to reach 1 bln cubic m. In 2014, these installations were captured by Russian troops and in early December 2015 towed from the Odessa deposits.

[44] Strilkove field is the only source of gas supply to the Ukrainian town Genichesk. In summer, excess production was pumped into the Glibovske underground storage (UGS) facility in Crimea and was used to satisfy peak demand of the town in winter. However, Russia blocked the supply of gas to Genichesk from the USG and used the situation for the purpose of an informational campaign (see section 3.8).

[45] For detailed information, see database "The Donbass Paradox". Access: http://www.theblacksea.eu/donbass/

[46] Starobeshevskaya TPP and Zuevskaya TPP, Zuevskaya experimental CHP power plant, "Donetsk Steel", "Yasinovatovskogo Coke", "Alchevsk Coke Plant", "Gorlovka Coke Plant", "Makeyevka Steel", "Alchevsk Metallurgical Plant", "Enakievo Steel", "Makiyivkoks", JSC "Silur", Concern "Stirol", Plant "Cargill" and "TPK Ukrsplav", four wind farms Lutuginsky, Krasnodon, Novoazovsk and Vitroenerhoprom.

[47] Prior to the outbreak of the war, more than 5,300 industrial enterprises were operating in the pre-war Donetsk and Luhansk oblasts. Damage to the region's industry is widespread and ranges from direct damage to industrial installations, to enterprises simply stopping production because of the lack of raw materials, energy, workforce or distribution channels. https://sustainablesecurity.org/2015/04/21/the-ukraine-conflicts-legacy-of-environmental-damage-and-pollutants-2/

Specifically, 85 out of a total of 150 Ukrainian coal mines (both state and privately owned) were seized in the occupied territories (i.e. more than 57% of mines in Ukraine). 35 of the 90 state-owned coal mines were on territory controlled by the Ukrainian government. Of critical importance to the Ukrainian energy sector was the loss of all anthracite coal (type A) being mined in the occupied territory. From the beginning of hostilities until the end of 2014, coal production in Ukraine decreased by 22% to 65 million tons. Overall, it produced 49 million tons of thermal coal (19% less than in 2013) and 16 million tonnes of coking coal (32% less). Production at state mines decreased by 27% to 18 million tonnes (36% of total).

Details of seized Coal mines are given below, details of seized assets in Donbas Oil and Gas sector are given in Appendix 4.

Name	Type of coal*	Function (Energy / Coke)	Production thousand ton (year 2013)	Address
Donets'k region				
SOE "DVEK"				
Cheliuskinciv mine	LFC	E	131,88	Donets'k
Zhovtnevyi rudnik mine	G	E	112,01	Donets'k
n.a. E.T.Abakumova mine	LFC	E	77,32	Donets'k
Lidiivka mine	G	E	9,47	Donets'k
n.a. M.I.Kalinina mine	B	C	55,35	Donets'k
Mospyns'ka mine	L	E	77,51	Donets'k
Trudivs'ka mine	LF	E	362,58	Donets'k
n.a. O.O.Skochyns'kogo mine	F	C	662,66	Donets'k
PJSC mine management "Donbas"				
Shheglovs'ka-Glyboka mine	C	C	516,00	Donets'k
Komunars'ka mine	L	E	642,11	Donets'k
SOE "Makiivvugillya"				
n.a. V.M.Bazhanova mine	C	C	13,03	Donets'k region, Makiivka city
Holodna Balka mine	L	E	562,81	Donets'k region, Makiivka city
n.a. V.I.Lenina mine	C	C	198,92	Donets'k region, Makiivka city
Kalynivs'ka-Chidna mine	C	C	368,04	Donets'k region, Makiivka city
Butivs'ka mine	G	E	427,57	Donets'k region, Makiivka city
Chaikine mine	F	C	193,82	Donets'k region, Makiivka city
n.a. S.M.Kirova mine	C	C	464,37	Donets'k region, Makiivka city
Yasinivs'ka-Gliboka mine	B	C	162,07	Donets'k region, Makiivka city
Pivnichna mine	C	C	56,98	Donets'k region, Makiivka city
SOE "Artemvugillya"				
n.a. M.I.Kalinina mine	B	C	216,97	Donets'k region, Horlivka city
n.a. K.A.Rumianceva mine	B	C	147,09	Donets'k region, Horlivka city
n.a. V.I.Lenina mine	C	C	161,82	Donets'k region, Horlivka city
n.a. Gajovogo mine	C	C	171,32	Donets'k region, Horlivka city

Name	Type of coal*	Function (Energy / Coke)	Production thousand ton (year 2013)	Address
Donets'k region				
SOE "Ordzhonikidzevuhillya"				
Yenakiivs'ka mine	L	E	153,29	Donets'k region, Shakhtars'kyy district, Maloorlivka village
n.a. Karla Marksa mine	B	C	76,78	Donets'k region, Yenakiyeve city
Poltavs'ka mine	L	E	124,23	Donets'k region, Yenakiyeve city
Vuhlehirs'ka mine	L	E	131,10	Donets'k region, Vuhlehirs'k city
Bulavyns'ka mine	L	E	107,51	Donets'k region, Yenakiyeve city
Ol'khovats'ka mine	L	E	90,01	Donets'k region, Yenakiyevecity
SOE "Shakhtars'kantratsyt"				
Ilovays'ka mine	L	E	303,89	Donets'k region, Khartsyzs'k city
n.a. 17 partz"yizdu mine	A	E	30,00	Donets'k region, Shakhtars'k city
Shakhtars'ka-Hlyboka mine	A	E	840,02	Donets'k region, Shakhtars'k city
SOE "Torezantratsyt"				
n.a. L.I.Lutuhina mine	A	E	394,57	Donets'k region, Torez city
Volyns'ka mine	A	E	179,27	Donets'k region, urban settlement Rozsypne
Progres mine	A	E	1030,33	Donets'k region, Torez city
SOE "Snizhneantratsyt"				
Udarnyk mine	A	E	91,27	Donets'k region, Snizhne city
Zorya mine	A	E	700,02	Donets'k region, Snizhne city
Enterprise "N.a. O.F.Zasyad'ka mine"	F	C	1423,71	Donets'k
PJSC "Komsomolets' Donbasu"	L	E	4028,38	Donets'k region, Shakhtars'kyy district, Kirovs'ke city
Closed joint-stock company	L	E	1451,00	Donets'k region, Zhdanovka city
Public JSC "Ukrvuhlebud"	F	C	466,39	Donets'k region
Small private enterprise's	A	E	701,10	Donets'k region
Luhans'k region				
SOE "Luhans'kvuhillya"				
Luhans'ke mine management	G	E	417,26	Luhans'k region, Luhans'k, urban settlement Yuvileyne
Lutuhins'ka mine	G	E	98,22	Luhans'k region, Lutuhins'kyy district, Heorhiyevka village
Cherkas'ka mine	G	E	13,31	Luhans'k region, Slov"yanoserbs'kyy district, Zymohir"ya-1 city
n.a. Artema mine	L	E	75,64	Luhans'k region, Pereval's'kyy district, Artemivs'k city
Nykonor-Nova mine	L	E	260,93	Luhans'k region, Zoryns'k-1 city
Fashchevs'ka mine	L	E	98,96	Luhans'k region, Pereval's'kyy district, Fashchivka urban settlement
n.a. XIX z"izdu KPRS mine	G	E	295,62	Luhans'k region, Lutuhyns'kyy district, Bile urban settlement
Verhel'ovs'ka	L	E	225,58	Luhans'k region, Bryanka city, Verhulivka-64 urban settlement
SOE "Pervomays'kvuhillya"				
Lomovats'ka mine	B	C	45,39	Luhans'k region, Bryanka city, Lomovats'ka urban settlement

Name	Type of coal*	Function (Energy / Coke)	Production thousand ton (year 2013)	Address
Donets'k region				
SOE "Donbasantratsyt"				
Cnyahynivs'ka mine	A	E	184,74	Luhans'k region, Krasnyy Luch city
Krasnoluchs'ka mine	A	E	249,00	Luhans'k region, Krasnyy Luch city
Novopavlivs'ka mine	A	E	56,63	Luhans'k region
Khrustal's'ka mine	A	E	160,92	Luhans'k region, Vakhrusheve city
Miusyns'ka ,ine	A	E	166,62	Luhans'k region, Krasnyy Luch city
n.a. "Izvestiya newspaper" mine	A	E	400,07	Luhans'k region, Krasnyy Luch city
Krasnokuts'ka mine	A	E	156,21	Luhans'k region, Krasnyy Luch city
SOE "Antratsyt"				
Partyzans'ka mine	A	E	400,01	Luhans'k region, Antratsyt city, Kripens'kyy urban settlement
Kripens'ka mine	A	E	1656,70	Luhans'k region, Antratsyt city, Kripens'kyy urban settlement
Komsomol's'ka mine	A	E		Luhans'k region, Antratsyt city, Dubivs'kyy urban settlement
SOE "Roven'kyantratsyt"				
n.a. F.E.Dzerzhyns'koho N 2 mine	A	E	1626,50	Luhans'k region, Roven'ky-4 city
Roven'kivs'ke mine management	A	E	590,38	Luhans'k region, Roven'ky-6 city
n.a. Kosmonavtiv mine	A	E	1387,41	Luhans'k region, Roven'ky city, Novo-Dar"yivka village
n.a. M.V.Frunze mine	A	E	1576,98	Luhans'k region, Roven'ky city, Yasenivs'kyy urban settlement
n.a. V.V.Vakhrusheva mine	A	E	1121,40	Luhans'k region, Roven'ky city, Yasenivs'kyy urban settlement
N 81 Kyivs'ka mine	A	E	438,91	Luhans'k region, Roven'ky city
SOE "Sverdlovantratsyt"				
Chervonyy partyzan mine	A	E	2596,62	Luhans'k region, Chervonopartyzans'k city
Dovzhans'ka-Kapital'na mine	A	E	1947,58	Luhans'k region, Sverdlovs'k city
Tsentrospilka mine	A	E	654,91	Luhans'k region, Sverdlovs'k city, Komsomol's'kyy urban settlement
n.a. Ya.M.Sverdlova mine	A	E	1067,25	Luhans'k region, Sverdlovs'k city
Kharkivs'ka mine	A	E	741,65	Luhans'k region, Sverdlovs'k city, Kharkivs'ke urban settlement
Public JSC "Krasnodonvuhillya"				
n.a. Barakova mine	F	C	1218,97	Luhans'k region, Sukhodil's'k city
Duvanna mine	F	C	280,01	Luhans'k region, Sukhodil's'k city
Molodohvardiys'ka mine	F	C	1297,54	Luhans'k region, Molodohvardiys'k city
Sukhodil's'ka-Skhidna mine	C	C	1047,91	Luhans'k region, Sukhodil's'k city
Horikhivs'ka mine	F	C	236,57	Luhans'k region, м.Молодогвардійськ
n.a. 50-richchya SRSR mine	F	C	316,49	Luhans'k region, Molodohvardiys'k city
Samsonivs'ka-Zakhidna mine	F	C	1343,90	Luhans'k region
State Public JSC "Bilorichens'ka mine"	G	E	1419,30	Luhans'k region, Lutuhyns'kyy district, Bilorichens'kyy urban settlement
LLC "Sadova mine"	A	E	591,47	Luhans'k region
Small private enterprise's	A	E	591,47	Luhans'k region

*Note:
A - anthracite (hard coal)
B - baking coal
C - coking coal
G - gas coal
F - fat coal
L - lean coal
LF - long-flame coal
LFC - long-flame gas coal

APPENDIX 4. MAIN GAS ASSETS SITUATED IN THE OCCUPIED TERRITORY OF UKRAINE

In the occupied territory of Donetsk region there are 38 gas distribution stations. The total daily volume of gas consumption is 1.406 million cubic meters, of which 366 thousand is used by industry and 1.04 million by the population.

In the occupied territory of Luhansk region there are 33 gas distribution stations. The total daily volume of gas consumption is 1.105 million cubic meters, of which industry consumes 390 thousand and population 715 thousand. In this area there are two compressor stations, Luhansk and Novodarevka, as well as the Vergunka UGS [308]. A detailed list is provided on subsequent pages.

UKRTRANSGAS objects in Donetsk and Luhansk region as of 06.10.2014	
On Ukrainian controlled territory	**On territory not controlled by Ukraine**
Gas distribution stations in Donetsk region	
Avdiivka	Donetsk 1
Olginka	Donetsk 2
Kurachove	Gas control points 1 Donetsk
Elektrostal	Teplichnyj
Volnovacha	LVZ
Vladimirovka	Makiivka
Novotroijizke	Makiivka severnaja
Selydove	Hanzhenkovo severnaja
Otscheretyne	Yenakiieve
Marjinka	Yenakievskaja PF
Elenovskij	Amvrosiivka
Uhledar	Metalist
Mariuopol 1	Amvrosiivcki
Mariuopol 2	Belojarovskij
Mariupolck	Horlivka 1
Pervomajsk	Horlivka 2
Volodarskogo	Stirol
Malinovka	Khartsyzk
Manhush	Zuhres 1
Yalta	Zuhres 2
Dzerzhinsky	Ilovaisk
Hursuf	Shakhtarsk
Kramatorsk	Druzhba
New Kramatorsk Machinebuilding Factory Konstantinovka 1	Snizhne
Konstantinovka 2	Panteleymonov
Konstanski	Razdolnoye
Lenina	Dokuchaievsk
Shirokij shljah	Snovsk
Slovjansk	Donskoye
Promin'	Starobesheve
Krasnyi Lyman	Kotovskovo

UKRTRANSGAS objects in Donetsk and Luhansk region as of 06.10.2014	
On Ukrainian controlled territory	**On territory not controlled by Ukraine**
Gas distribution stations in Donetsk region	
Pravdinsk	Hirnyk
Malinovka	Zorya
40 let oktjabrja	Novozarivka
Slovianska heat power station	Telmanove
Shidlov	Novoazovsk
Uljanovo	Pobeda
Druzhkivka	Sakhanka
Kondratyevka	**Total: 38 gas distribution stations**
Artemivsk	
Bachmutsky	
Pravda Kirova	
Timirjazevski	
Kirova	
Pokrovsk	
Gorkogo	
Chasiv Yar	
Siversk	
Dzerzhinsk	
Shherbinov	
Krasnoarmeysk	
Uglegorsk	
Kozanenko	
Loskutivka (compressor station)	
Total: 54 gas distribution stations, 1 compressor station	

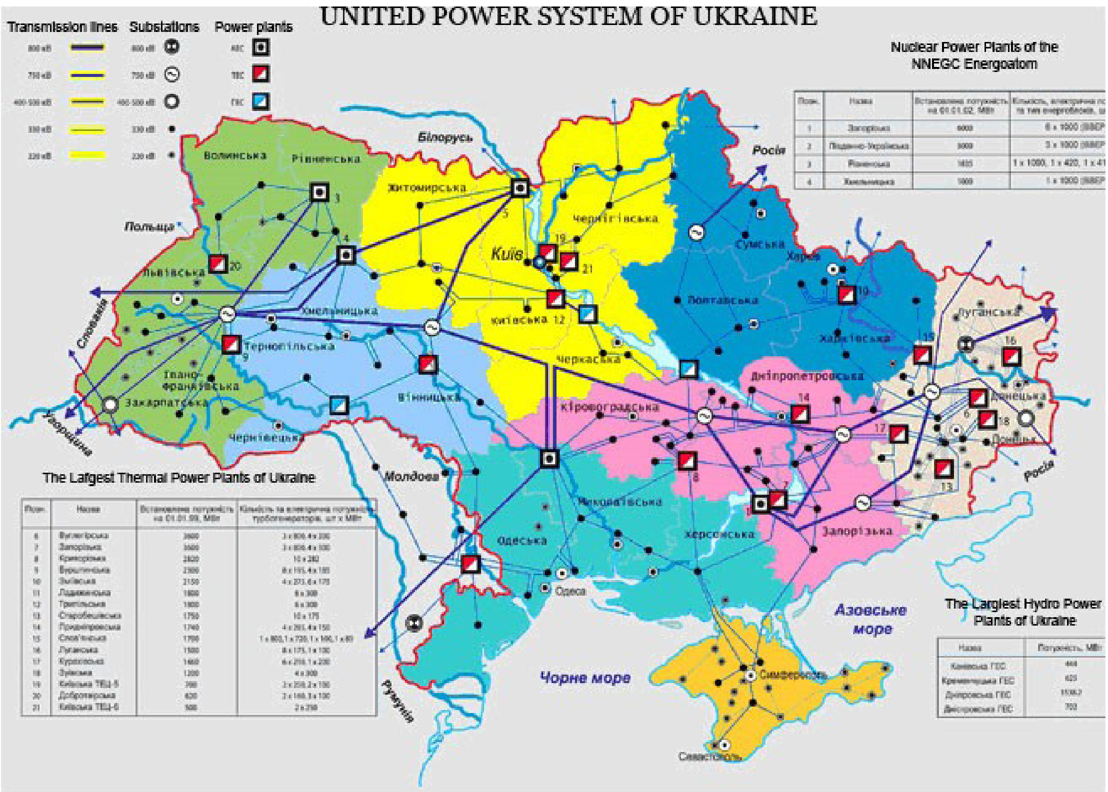
UKRTRANSGAS objects in Donetsk and Luhansk region as of 06.10.2014	
On Ukrainian controlled territory	**On territory not controlled by Ukraine**
Gas distribution stations in Luhansk region	
Sievierodonetsk	Alchevsk
Nova Astrakhan'	Slovianoserbsk
Lysychansk	Oktyabrsky
Lysychansk oil refinery	Rodakove
Lysychansk oil pump station	Pervomaisk
Syrotyne	Stakhanov
Rubizhne	Luhansk 2
Kreminna	Zymohiria
Krasnorichens'ke	14 let oktjabrja
Krac Pakovka	Litvinovo
Zorya Luhansk	Novoannovski
Karbonit	Krasnodon 1
Myrna Dolyna	Simeikyne

UKRTRANSGAS objects in Donetsk and Luhansk region as of 06.10.2014	
On Ukrainian controlled territory	**On territory not controlled by Ukraine**
Gas distribution stations in Luhansk region	
Krymske	Izvaryne
Luhansk	Krasnodon 2
Popasna	Antratsyt
Ukraina	Yasynivka
Artyoma	Rovenky
Pobeda	Blahivka
Rodina	Daryevka
Rascvet	Dyakove
Schast'e	Sverdlovsk
Suvorova	Rovenkovski
Artyoma	Dolzhans'kyi
Kalinina	Novoborovytsi
Mykhailyuky	Medvezhanskaja
Novoaidar	Luhansk 1
Starobilsk	Verhunka
Technikum	Krasnyi Luch
Bondarevo	Pervozvanivka
Tets'ke	Lutuhyne
Novopskov	Petrovske
Belolucsk	Vergunskoe
Kamianka	Luhansk compressor station
Bilokurakyne	Novodar'ivka compressor station
Pysarivka	Vergunska underground gas station
Zorya	**Total: 33 gas distribution stations, 2 compressor stations, 1 underground storage**
Markivka	
Milove	
Lesnaja Poljana	
Bilovods'k	
Shelestivka	
Prosyane	
Myrnyi	
Yevsuh	
Kolyadivka	
Voyevodskoye	
Konoplyanivka	
Popivka	
Kolomyichykha	
Svatove	
Novopekov	
Krasnopopovka underground storage	
Total: 51 gas distribution stations, 1 compressor station, 1 underground storage	

APPENDIX 5. THE UNIFIED ENERGY SYSTEM OF UKRAINE

The Unified Energy System of Ukraine (UESU) is the foundation of the national electric power industry. The UESU ensures centralised power supply to domestic consumers and interacts with the electric power systems of adjacent countries (import and export). It consolidates the electric power generating facilities and distribution networks of Ukrainian regions, which are interlinked by system-forming power transmission lines of 220 – 750 kW.

Operational and technological management of the UESU is executed on a centralised basis by the state enterprise National Energy Company "Ukrenergo". The scheme of UESU below shows its 8 subsytems in different colors. Their technical and operational parameters constantly change. The site of Ukrenergo provides regularly updated parameters of the subsystems.



APPENDIX 6. DAMAGE TO THE ELECTRICAL POWER INFRASTRUCTURE, AS RECORDED BY THE OSCE SMM

Date of attack	Location	Details of the impact	Possible attacker	Link
06.08.2014	Luhansk city	The main generator was damaged during recent shelling. Luhansk city is completely left without electricity and subsequently internet coverage.	unknown	309
16.09.2014	Vuhlehirsk (62 km north-east of Donetsk)	The SMM observed few people on the streets, together with several damaged buildings and electricity lines.	unknown	310
24.10.2014	Hranitne (90 km south-east of Donetsk city)	The town had been shelled six times. The electricity supply – only just recently restored – had been cut as a result of recent shelling.	The impacts suggested that the rounds had been fired from "DPR" – controlled territory to the east of the town.	311
19.01.2015	Debaltseve (55 km north-east of Donetsk)	At least 30 Grad rockets impacted in and around the centre of Debaltseve killing three civilians and wounding twelve. The SMM observed that the rockets had caused significant damage to buildings and covered an area of approximately one square kilometre. Most of the damage consisted of broken windows, felled trees and downed power lines.	A crater analysis performed by the SMM showed that the Grad rockets came from a western direction, the direction of "DPR"-controlled Horlivka.	312
05.02.2015	Sartana (90 km south of Donetsk). The area (2 km square), is located south-west of Ukrainian Armed Forces positions on the outskirts of the village.	The area was hit by up to 30 shells in a 15-20 minute period. The SMM saw damage to 18 houses and observed that power lines were cut.	An analysis of four craters by the SMM determined that they were caused by mortars (120mm and 82mm), likely fired from a north or north-easterly direction (*"DPR"-controlled*).	313
30.03.2015	Shyrokyne (20 km east of Mariupol)	Fallen power lines	-	314
04.06.2015	Hranitne (47 km north-east of Mariupol)	Electricity supply is frequently interrupted due to damage to the power line caused by shelling.	The SMM analyzed 15 recent craters and assessed that four of them were caused by mortar shelling originating from the south-east (*"DPR"-controlled*).	315
05-06.2015	Chermalyk (31 km north-east of Mariupol)	The village was facing a lack of electricity supply and running water due to damage of the electrical lines.	unknown	316

Date of attack	Location	Details of the impact	Possible attacker	Link
06.2015	Luhansk region (government-controlled)	Around 20,000 people were left without access to water in government-controlled Popasna, Bobrove, Bobrovske, Toshkivka, Nyzhne, Svitlychne, Novotoshkivske and in LPR-controlled Pervomaisk. Due to the shelling, electricity cables had been destroyed in government-controlled Trokhizbenka, Kriakivka, Orikhove, Lobachevo, Lopaskine, Gravove, Orikhove, Krymske, Novozvanivka and Troitske.	unknown	
29-30.07.2015	Dzershinsk (54 km north of Donetsk)	At least five houses had suffered direct hits, destroying roofs and walls. Telephone, electricity and gas infrastructure had also been affected and repair works were observed by the SMM.	The SMM observed 12 impacts caused by mortar and artillery and conducted crater analysis at two locations. The SMM assessed the direction of fire to have been from an east-south-east direction (*"DLPR"-controlled*).	
15.08.2015	Lomuvatka (57 km south-west of Luhansk)	The SMM visited five sites in residential areas of the village and observed damage to windows and walls of a house and downed power lines.	The SMM analysed craters at one site and assessed that they had been caused by howitzer (D30 122mm).	
17.08.2015	Sartana (15 km north-east of Mariupol),	Electricity, gas and water supplies had been cut in at least some parts of the village because of the shelling.	The SMM observed and carried out analysis on 11 craters, concluding that either 122 or 152mm artillery rounds – mostly fired from the east – had caused them (*"DPR"-controlled*).	
21.08.2015	Lebedynske (16 km north-east of Mariupol)	The electricity line and gas pipeline were damaged.	The SMM observed six fresh craters and assessed that five of them were caused by 82mm mortar shells fired from a south-easterly direction, while the sixth was caused by a calibre above 120mm originated from the same direction (*"DPR"-controlled*).	
21-23.08.2015	Pervomaisk (57 km west of Luhansk)	The chief engineer and deputy chief engineer of the local power plant showed the SMM damage to the plant's transformer, which they said had been hit by 16 shells.	The SMM analysed 14 craters, assessed to have been caused by 82mm and 122mm shells, all fired from the north.	
08.2015	Shchastia (20 km north of Luhansk)	The high-voltage electricity cables, originating from the power station in government-controlled Shchastia (20km north of Luhansk), were damaged in several places as a result of shelling.	unknown	

Date of attack	Location	Details of the impact	Possible attacker	Link
01.12.2015	Kriakivka (37 km north-west of Luhansk)	The power transformer had been damaged by small-arms fire.	The SMM observed two bullet holes in the two oil-cooling containers and assessed the direction of fire was from the south-east (*"LPR"-controlled*).	
30-31.01.2016	Zaitseve (50 km north-east of Donetsk)	The SMM observed in the area of an electricity substation five fresh craters, which it assessed had been caused by mortar rounds.	Mortar rounds fired from the south-south-east (*"DLPR"-controlled*).	
02-03.2016	Avdiivka (17 km north of Donetsk)	An electricity pylon was allegedly damaged recently by shelling and as a result some villages in the area, such as Vasylivka (government-controlled, 18km north-east of Donetsk), had no power.	unknown	
24.04.2016	Pravdivka (36 km north of Donetsk)	A power line was damaged.	The SMM observed a crater, assessed as having been caused by a 152mm artillery round fired from an east-south-easterly direction (*"DLPR"-controlled*).	
19.07.2016	Yasynuvata ("DPR"-controlled, 16 km north-east of Donetsk)	The electric power lines near Yasynuvata were damaged due to shelling, causing the local water filtration station to stop operating. According to the electric company, the damaged power line is the main line between Makiivka-Yasynuvata-Avdiivka that supplies Avdiivka city, Avdiivka coke plant and the Donetsk water filtration station. According to the water company, Avdiivka; the Avdiivka coke plant; and 50 per cent of Yasynuvata, Krasni Partizan, Verkhnotoretske and the surrounding villages are without potable water, with approximately 40,000 people affected by the water shortage.	unknown	
21.07.2016	Avdiivka (17 km north of Donetsk),	Downed power lines that cut electricity to government-controlled Avdiivka (17km north of Donetsk), parts of "DPR"-controlled Yasynuvata (16km north-east of Donetsk) and the water filtration station situated between these two cities.	The SMM heard 25 undetermined explosions and five explosions assessed as impacts of 82mm mortar rounds 2-5km east, south-east and north-west; one explosion assessed as an outgoing 122mm artillery round 2-3km south-east; and bursts of heavy-machine-gun fire 4km east of its position (*"DLPR"-controlled*).	
30.07.2016	Avdiivka (17 km north of Donetsk)	An electricity pole had been snapped in half and had fallen	unknown	

Date of attack	Location	Details of the impact	Possible attacker	Link
03.08.2016	Avdiivka (17 km north of Donetsk)	Water and power supply to the town had been interrupted as shelling had caused damage to power transmission lines and to the Donetsk water filtration station located between Avdiivka and Yasynuvata.	unknown	
22.08.2016	Popasna (69 km west of Luhansk)	The SMM assessed that the projectile had hit the electricity pole next to a house causing a break in its power supply.	The SMM analysed a fresh crater, concluding that it had been caused by a recoilless gun (SPG-9, 73mm) round fired from an easterly direction (*"LPR"-controlled*).	
24.08.2016	Stanytsia Luhanska (16 km north-east of Luhansk)	An electricity line over a roof had been severed. The SMM also observed a hole in the middle of the roof of the same house.	The SMM observed fresh craters in the garden of the house and assessed that the damage had been caused by three or four rounds from an automatic grenade launcher (AGS-17) fired from an undetermined direction.	
29.08.2016	Troitske (69 km west of Luhansk)	At the impact sites the SMM observed a small hole in the roof of one house caused by shrapnel, several broken windows in another house and a severed electrical line at a third site.	The SMM was able to analyse three of the craters and assessed them as caused by 122mm artillery rounds fired from an easterly direction (*"LPR"-controlled*).	
18-19.10.2016	Vynohradne (10 km east of Mariupol)	The SMM noted damage to civilian infrastructure, including severed gas pipelines and power lines.	The SMM saw five impacts, four of which were in the yards of civilian houses and one at a field 50m from the residential area, assessed as caused by 122mm artillery shells, fired from an easterly direction (*"DPR"-controlled*).	
20.10.2016	Krasnohorivka (21 km west of Donetsk)	It observed shrapnel damage to the wall of an electricity sub-station and damage from a direct hit to the roof of the sub-station.	The SMM assessed three of the impacts as most likely having been caused by mortar rounds fired from an easterly direction (*"DPR"-controlled*).	
13.01.2017	Novozvanivka (70 km west of Luhansk)	Damaged electric lines.	The SMM assessed two of the craters as caused by artillery (152mm) rounds and one by a mortar (82mm) round from an easterly direction (*"DLPR"-controlled*).	
14.01.2017	Novoselivka (31 km north-east of Donetsk)	Damage to a concrete electric pole.	The SMM assessed the damage to have been caused by 120mm mortar fired from a south-south-easterly direction (*"DLPR"-controlled*).	

APPENDIX 7. EXAMPLES OF INFRASTRUCTURE RECOVERY BLOCKING, AS RECORDED BY THE OSCE SMM

Date	Location	Details of the impact	Possible attacker	Link
Recovery of power lines, electricity supply				
14.07.2015	Marinka (23 south-west of Donetsk),	The SMM could not facilitate repair works by the local administration on power lines in Marinka (government-controlled), as the area was not demined adequately.	unknown	
20.10.2015	Obozne (18km north of Luhansk)	The SMM heard a large explosion in the area of the repair site. According to a dozen electricity company workers (men, 25-45) who had been involved in the repair works, the company truck had hit an anti-tank mine that also set off an anti-personnel mine. They told the SMM that no one was injured, but the truck was heavily damaged.	unknown	
24.11.2015	Horlivka (39km north-east of Donetsk) and Artemove, now called Bachmut (40km north of Donetsk)	Representatives of the energy company DTEK in both "DPR"-controlled Horlivka and government-controlled Artemove told the SMM that planned demining and repair works on power lines were still pending, citing lack of security guarantees and on-going fighting in the area.	unknown	
02.03.2016	Kominternove and Vodiane (19km north-east of Mariupol)	On the road between Kominternove and Vodiane the SMM observed at least six newly-placed anti-tank mines, hidden under bushes that blocked the road 100m from a downed concrete electricity pole.	unknown	
05.03.2016	Horlivka (39km north-east of Donetsk) and Artemove, now called Bachmut (40km north of Donetsk)	The SMM monitored repair work to electricity power supply lines between government-controlled Artemove and Horlivka. The SMM eventually left the area due to the close proximity of incoming explosions, including three 82mm mortar impacts approximately 800m south-east of its position. The SMM was able to return to the area on 6 March and observed that work continued during the day without similar interruptions.	unknown	
29.07.2016	Zolote (61km north-west of Luhansk)	In Zolote repair work on electrical power lines were interrupted. The SMM spoke with the local civil-military co-operation representative who told the SMM that the workers were leaving the area due to the sporadic explosions and the security of the workers could not be guaranteed. The SMM saw the electric company workers to leaving the area.	unknown	
03.02.2017	Kamianka	The repair team tasked with fixing the power line in government-controlled Kamianka could not reach the damaged lines, citing safety concerns following shelling in the area.	unknown	

Date	Location	Details of the impact	Possible attacker	Link
Recovery of gas infrastructure				
12.02.2016	Marinka (23km south-west of Donetsk)	Whilst facilitating and monitoring repairs of gas pipelines in government-controlled Marinka, the SMM heard between 13:07 and 14:07 six undetermined explosions, bursts of small-arms fire and single shots, at locations ranging from 0.5-2km to the east of its position. Due to security considerations, the repair works had been suspended upon the decision of the Ukrainian Armed Forces in Marinka.	*Shelling from "DPR"-controlled territory*	
25.02.2016	Marinka (23km south-west of Donetsk)	In Marinka (government-controlled) a Ukrainian Armed Forces officer at the Joint Centre for Control and Co-ordination (JCCC) told the SMM that repairs to the gas pipeline in areas close to the contact line have been on hold since 13 February as "DPR" members have not provided security guarantees.	unknown	
02.03.2016	Marinka (23km south-west of Donetsk)	The SMM heard exchanges of fire between Marinka and Oleksandrivka, following which the Ukrainian Armed Forces officer requested that workers withdraw. By 12:45hrs, JCCC representatives had arranged a ceasefire and repair workers returned to the site. At 13:35hrs an intensive exchange erupted on the eastern edge of Marinka, forcing workers to leave after installing 40m of gas pipeline.	unknown	
06.03.2016	Petrovskyi district of Donetsk city (20km south-west of Donetsk city centre)	On 6 March, while monitoring repair work to a gas pipeline in "DPR"-controlled Petrovskyi district of Donetsk city, the SMM heard 20 bursts and nine single shots of small-arms fire approximately 500m west of its position. "DPR" members present at the site told the SMM that the weapons were likely being fired from neighbouring "DPR" forward positions.	unknown	
12.03.2016	Marinka (23km south-west of Donetsk)	In co-ordination with Ukrainian and Russian Federation Armed Forces JCCC officers, the SMM monitored on-going repair works to gas pipelines in government-controlled Marinka. Whilst there, in the morning hours, the SMM heard ten single shots of small-arms fire and ten bursts of heavy-machine-gun fire 1-2km south-east of its position. Due to on-going shooting in the area, repair work was temporarily halted.	*Shelling from "DPR"-controlled territory*	
31.03.2016	Marinka (23km south-west of Donetsk)	The SMM monitored – on both sides of the contact line - repairs to a gas pipeline near government-controlled Marinka. Works were suspended twice due to ceasefire violations in the area.	unknown	

Date	Location	Details of the impact	Possible attacker	Link
25.04.2016	Marinka (23km south-west of Donetsk)	In government-controlled Marinka and "DPR"-controlled Oleksandrivka the SMM was present to monitor scheduled repair works on a gas pipeline. Workers were, however, forced to leave the area as numerous ceasefire violations occurred in close proximity. In total, the SMM in Marinka between 09:55 and 11:11 heard two undetermined explosions, 49 single shots of small-arms fire and two bursts of heavy-machine-gun fire 0.5-2km north-east, east-north-east and south of its position. The SMM engaged both Ukrainian Armed Forces and Russian Federation Armed Forces members of the Joint Centre for Control and Co-ordination and "DPR" members, in order to facilitate adherence to the ceasefire, but to no avail.	Shelling from "DPR"-controlled territory	
26.04.2016	Marinka (23km south-west of Donetsk)	While monitoring planned gas pipeline repairs in government-controlled Marinka, the SMM patrol in Marinka heard three rounds of sniper fire 1-2km east-south-east of its position. The director of the gas pipeline company, present at the site, cancelled the repair works and the workers left the area after having worked for half an hour.	Shelling from "DPR"-controlled territory	
30.05.2016	Marinka (23km south-west of Donetsk)	The SMM continued to monitor the repair of gas pipelines between government-controlled Marinka and "DPR"-controlled Oleksandrivka. The SMM was forced to withdraw from the area and work was suspended on the pipeline because of sporadic small-arms fire in the vicinity.	unknown	
31.05.2016	Marinka (23km south-west of Donetsk)	The SMM continued to monitor the repair of gas pipelines between government-controlled Marinka and "DPR"-controlled Oleksandrivka. The SMM was forced to withdraw from the area and work was suspended because of sporadic ceasefire violations in the vicinity,	unknown	
Recovery of water supply systems				
07.08.2016	Donetsk region in locations between "DPR"-controlled Spartak (9km north-west of Donetsk city centre) and government-controlled Avdiivka (14km north of Donetsk) and between government-controlled Maiorsk (45km north-east of Donetsk) and "DPR"-controlled Horlivka (39km north-east of Donetsk)	In both areas, the SMM facilitated a local ceasefire to enable repairs to be carried out by *Voda Donbassa* workers. In both locations the repair works had started but were disrupted by ceasefire violations observed by the SMM. The SMM heard continuous incoming and outgoing mortar as well as multiple bursts of heavy machine gun fire. The SMM attempted numerous times and asked the parties to respect the ceasefire and honour their commitments and written security assurances given to the SMM. Since the shelling continued, the workers stopped their activities for the day at both locations and the SMM also withdrew.	unknown	

APPENDIX 8. TECHNICAL CHARACTERISTICS OF UKRAINIAN TPPS IN 2014

Name, total capacity, MW	Number x capacity of units, MW	Type of boiler	Steam productivity, t/h	Type of fuel*
Starobeshivska, 1975 MW	9x210 1x175	CKS-210 TP-100	640 670	A A
Kurakhivska, 1520 MW	5x220 2x210	TP-109 TP-109	640 640	P/p
Lughanska, 1460 MW	7x200	TP-100	640	A
Zuivska, 1270 MW	4x320	TPP-312A	950	P/p
Slovianska, 880 MW	1x800 TU – 80 CKS 2x330	TPP-200-1	2550	A A P/p
Zaporizhzhska, 3620 MW	4x315 3x800	TPP-312A TGMP-204	950 2550	G Gas/mazout
Kryvorizhska, 2880 MW	4x315 5x282	TPP-210A P-50	475x2 475x2	L
Prydniprovska, 1765 MW	2x285 2x285 4x150	TPP-210 TPP-110 TP-90	475x2 950 500	A, L A, L A, L
Burshtynska, 2330 MW	8x200 4x185	TP-100A TP-100	640 640	G
Ladyzhyunska, 1800 MW	6x300	TPP-312	950	G
Dobrotvirska, 500 MW	2x150 2x100	TP-92	500	G G
Vyglegirska, 3600 MW	4x300 3x800	TPP-312A TGMP-204	950 2550	G Gas/mazout
Zmiivska, 2260 MW	4x320 6x175	TPP-210A TP-100	475x2 640	A,L A,L
Trypilska, 1800 MW	4x320 2x300	TPP-210A TGMP-314	475x2 950	A Gas/mazout
Kyivska CHP-5, 700 MW	2x250 2x100	TGMP-314A	950	-"-
Kyivska CHP-6, 500 MW	2x250	TGMP-344A	950	-"-
Kharkivska CHP-5 , 470 MW	1x250 2x110	TGMP-344A	950	-"-

*A – anthracite (hard coal); G – gas coal; L – lean coal; P/p – industry product.

TPP colored:
in red - seized at occupied territory
in blue - close to front line and were damaged
in black – at the territory controlled by Ukraine

APPENDIX 9. TECHNICAL CHARACTERISTICS OF UKRAINIAN NPPS

Energoatom corporate web-page: http://www.energoatom.kiev.ua/en/

Zaporizhzhya NPP (ZNPP) - http://www.energoatom.kiev.ua/en/separated/npp_zp/

Rivne NPP (RNPP) - http://www.energoatom.kiev.ua/en/separated/npp_rivne/

South-Ukraine NPP (SUNPP) - http://www.energoatom.kiev.ua/en/separated/npp_su/
Khmelnitsky Nuclear Power Plant (KhNPP) - http://www.energoatom.kiev.ua/en/separated/npp_khmelnytska/

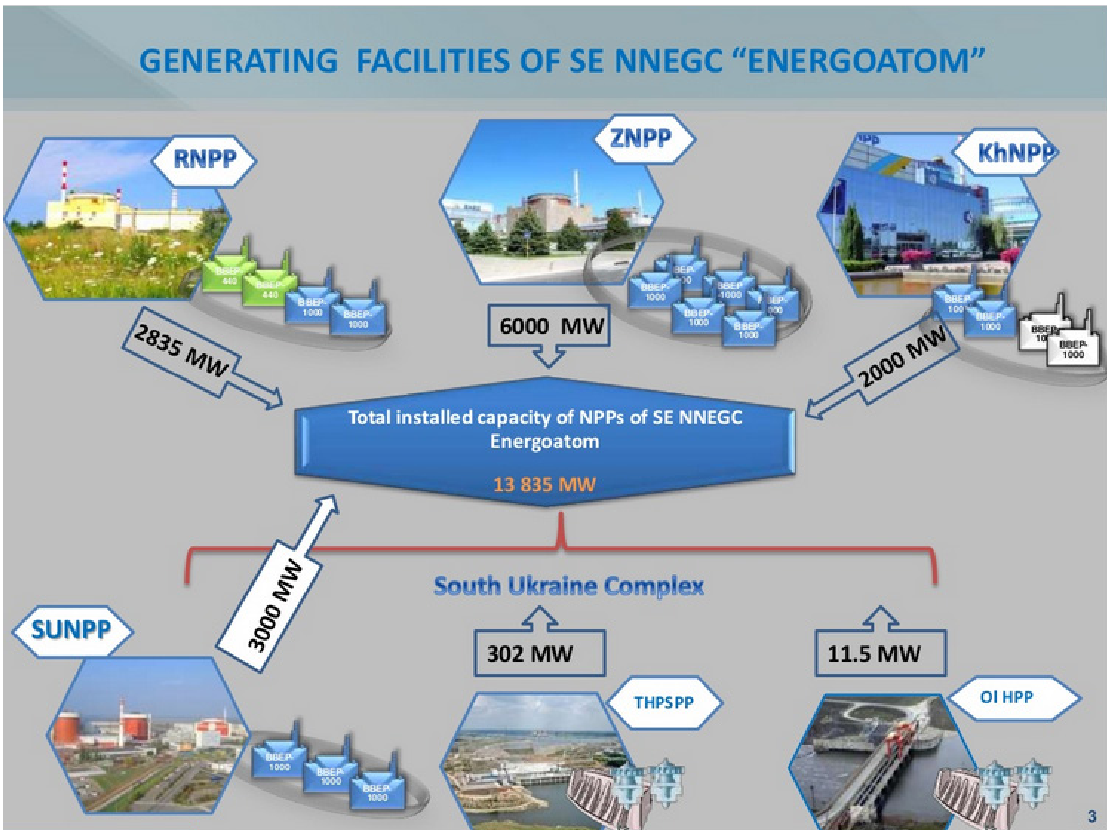
The Presentation to the speech President SE NNEGC "Energoatom" Yuriy Nedashkovsky at the Ukrainian Energy Forum 2017 of Adam Smith Conferences (02.03.2017). http://www.energoatom.kiev.ua/en/press/presentations/46471-presentation_to_the_speech_president_se_nnegc_energoatom_yuriy_nedashkovsky_at_the_ukrainian_energy_forum__of_adam_smith_conferences/

Technical details on Energoatom performance for 2016: http://www.energoatom.kiev.ua/files/file/tep_12_2016_balans.pdf

Appendix 10. Basic countermeasures (on the part of Ukraine) to the hybrid aggression of Russia

1) At the very beginning, Ukraine reacted to the developing situation using available forces and resources . Later some practical improvements were made:

- it has revised the system of territorial defense, where among other tasks, some infrastructure assets were put under protection;
- it has re-established the National Guard of



Ukraine as a law enforcement unit with heavy weaponry that was able to repel attacks against protected objects and was tasked to protect critical infrastructure;

- it has strengthened the protection of transport infrastructure, such as railways, bridges, ports etc. by special agencies (the National Guard, Special Service for railways);
- it has taken decisions on reducing Ukrainian dependence on Russian infrastructure via diversification of energy supply routes;
- it has improved the cooperation of local authorities with various state departments (State Service of Ukraine for Emergency Situations, Army Forces, National Guard, Security Service) in terms of strengthening the protection and recovery of critical infrastructure;
- it has established a communication channel between fighting parties with the support of third parties: Normandy Format, Minsk Negotiation Group, OSCE Special Monitoring Mission to Ukraine, Joint Coordination Center (Ukrainian and Russian representatives);
- it has ensured the involvement of the OSCE Special Monitoring Mission to Ukraine in the process of securing a ceasefire during repair work on infrastructure restoration.
- The State commission on Technogenic and Ecological safety and emergencies (State Emergency Committee) was established as a permanent body to coordinate the activities of central and local executive authorities related to the provision of technogenic and ecological safety of population and territories in emergency situations, organisational measures against terrorism and military threats, prevention of emergency situations and response to them in January 2015.
- There were also improvements to a number of legal acts concerning national security, including the protection of critical energy infrastructure:
- in May 2015 a new version of Ukraine's National Security Strategy was adopted that identified security threats including critical infrastructure and priorities of security, including:
  - o to comprehensively comprehend the legal basis of the critical infrastructure, securing the systems of state control over security;
  - o to strengthen the protection of critical infrastructure, including energy and transport;
  - o to establish cooperation between different entities to protect critical infrastructure, develop public-private partnership in the field of disaster prevention and response;
  - o to develop and implement mechanisms for information sharing between government agencies, private sector and public regarding threats to critical infrastructure and protection of sensitive information in the field;
  - o to prevent man-made accidents and prompt an adequate response to them, localise and minimise their consequences;
  - o to develop international cooperation in this field;
- in 2015 the Design Based Threat to nuclear facilities, nuclear materials, radioactive waste and other sources of ionizing radiation in Ukraine was clarified, considering the significant changes in the security situation as a result of Russia's aggression;
- in September 2015 a new edition of the Military Doctrine of Ukraine was adopted, which specified tasks and authority of security and defense sector agencies to protect critical infrastructure;
- in April 2015 a Law of Ukraine on the Natural Gas Market was adopted, which determines the legal framework for security of natural gas supply in various crisis situations, responsible entities and a list of measures to be taken;
- in November 2015 a National Action Plan further detailed the security of natural gas supply in various crisis situations;
- in March 2016 there was a new Concept of the security and defense of Ukraine, where separate attention is focused on providing counterintelligence protection of state government

and critical infrastructure of strategic importance;

- in April 2017 a Law of Ukraine on the Electricity Market determined the legal framework for the safe supply of electricity to consumers and criteria for the rules on the security of supply of electric energy.
- Legislation concerning cybersecurity was also adopted:
- in March 2016 there was a new Strategy for Cybersecurity, which also reflected the issue of forming the legal framework for cybersecurity, the creation of a cybersecurity system, the strengthening of the subjects of the security and defense sector and the provision of cyber security critical information infrastructure;
- to implement the cybersecurity strategy, a plan of measures was approved in 2017;
- in 2017 the National Coordinating Center for Cybersecurity of Ukraine was established in accordance with the Strategy for Cybersecurity of Ukraine, which is the working body of the National Security and Defense Council of Ukraine;
- in February 2017 there was a decision of the National Security and Defense Council of Ukraine, approved by the President of Ukraine, on threats to cybersecurity of the state and urgent measures for their neutralisation, which emphasized the need to prepare legislative proposals for defining the requirements for cyber security of critical infrastructure objects and to implement the Convention on Cybercrime;
- in August 2017 there was a decision of the National Security and Defense Council of Ukraine, approved by the President of Ukraine, on the state of implementation of the decision of the National Security and Defense Council of Ukraine dated December 29, 2016 on the threats to the cybersecurity of the state and urgent measures for their neutralization, which emphasized the urgent implementation of such a decision.

2) Building up of a state system for critical infrastructure protection, aimed at improved resilience of the infrastructure against hazards of any kind, including terrorist and cyber threats.
On the request of Ukraine , the UN Security Council adopted Resolution 2341 which calls on Member States to address threats against critical infrastructure and to establish an international framework for critical infrastructure protection and to set the measures the UN Secretariat and Member States have to perform.

3) Improving the effectiveness of strategic communications in responding to Russian propaganda campaigns, to insure support from Ukrainian society in the face of the aggressive strategic communications policy of the RF.

4) Increasing the defensive capacity of the army.

Faced with potential evolutions in military practice, the Alliance should be ready to respond by understanding the new environment and the effects of hybrid warfare upon energy security and CEIP, while developing appropriate tools and mechanisms to mitigate this threat. A better analysis and understanding of the evolution of Russian military doctrine and strategy should also provide some predictive power about future threats.

ATTACHMENT. INFORMATION DATABASE ON MONITORING OF THE EVENTS RELATED TO THE OPERATION OF ENERGY INFRASTRUCTURE IN UKRAINE (IN THEIR ORIGINAL LANGUAGES)

The information posted on official websites of Ukrainian authorities and international organisations was analysed within the project framework.

1) National Security and Defense Council of Ukraine http://www.rnbo.gov.ua/

2) Security Service of Ukraine https://ssu.gov.ua/ (up to 26.05.2016 http://www.sbu.gov.ua/)

3) Ministry of Defense of Ukraine http://www.mil.gov.ua/

4) Information Analysis Center National Security of Ukraine http://mediarnbo.org/

5) State Border Guard Service of Ukraine http://dpsu.gov.ua/

6) The State Emergency Service of Ukrain http://www.dsns.gov.ua/

7) Ministry of Energy and Coal Industry of Ukraine http://mpe.kmu.gov.ua/

8) Donetsk regional state administration http://dn.gov.ua/ (up to 10.10.2016 http://donoda.gov.ua/)

9) Luhansk regional state administration http://loga.gov.ua/ (up to 01.08.2016 http://old.loga.gov.ua/)

10) OSCE Special Monitoring Mission to Ukraine http://www.osce.org/ukraine-smm/

11) NATO Strategic Communications Centre of Excellence. http://www.stratcomcoe.org

12) EU vs Disinformation https://euvsdisinfo.eu/ru/ & East Stratcom Task Force http://us11.campaign-archive2.com/

Data from news sites and information-analytical sites of Ukraine (including the so-called "Donetsk and Luhansk People's Republics"), Russia and other countries were also analyzed. Below are references to the most representative publications (in their original languages).

Note: to follow some links please copy an address to a query box in your Internet browser.

ABBREVIATIONS

ADCS – Automatic Dispatcher Control System (SCADA analog)
AFU – Armed Forces of Ukraine
ATC SSU – Antiterrorist Center at the Security Service of Ukraine
ATO – Antiterrorist operation
CEI – Critical Energy Infrastructure
CI – Critical Infrastructure
CMU – The Cabinet of Ministries of Ukraine
DPR-LPR – So-called Donetsk and Luhansk People's Republics
GTS – Gas Transit System
ICS – Indusrtrial Control System
JCCC – Joint Centre for Control and Co-ordination
MLRS – Multiple Launch Rocket System
NISS – National Institute for Strategic Studies
NPP – Nuclear Power Plant
NSDC – The National Security and Defense Council of Ukraine
SDDLR – Some districts of Donetsk and Luhansk regions
SCADA – Supervisory Control And Data Acquisition
SMM – OSCE Special Monitoring Mission to Ukraine
SSU – The Security Service of Ukraine
TPP – Thermal Power Plant
UESU – The Unified Energy System of Ukraine

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Poland's Energy Diplomacy, The Antithesis to Antagonistic Global Energy Actors

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ABSTRACT

The global energy market has witnessed numerous superpower competitors attempting to use the weaponization of energy trade or aggressive Energy Diplomacy to impose energy economic dominance. As an antithesis to this antagonistic strategy, Poland has risen to demonstrate the model to repress this aggressive diplomatic approach to gain energy diversification and stimulate its national productivity. Poland's revamped Energy Diplomacy founded on the diversification of energy imports, competitive strategy in the global energy marketplace, and resounding economic and energy alliances with the Former Eastern Bloc Countries has served as an international model for national prosperity and map to energy independence. Through the Porter's diamond model, it can be demonstrated how Poland has been able to exploit its attributes to include factor and demand conditions, supporting industries, and firm strategy to make itself independent and to introduce a counterstrategy against Russia and China's weaponization of energy diplomacy.

KEYWORDS

Energy, Security, Diplomacy, Poland, Weaponization

INTRODUCTION

In the globalization and post-COVID 19 era, new laws of global commerce, supply chain diversification, and economic prosperity will be written. In the context of global prosperity, the production, transport, market, and consumption of energy serves as the cornerstone to sustain the world populace. The global energy market has witnessed numerous superpower competitors attempting to use the weaponization of energy trade or aggressive Energy Diplomacy to impose energy economic dominance. Facing the beacon of this antagonistic global energy market diplomatic sphere, Poland has risen to demonstrate the model to gain energy diversification to stimulate its energy prosperity.

Over the past three decades, there have been many political and economic changes in the Republic of Poland. The collapse of communism, the accession to NATO and the European Union as well as the Ukrainian-Russian crisis have shaped Poland's revamped Energy Diplomacy and Policy. Although Polish natural resources currently are not sufficient to grant consumers the required energy sources for the functioning of the community, Poland has invested in industrial policies, international development, and infrastructure to maximize its energy independence.
That said, Poland should continue to develop industrial infrastructure, diversify suppliers, and seek new energy alliances to reduce dependence on a single supplier, which is a threat to the country's economy.

1. POLISH PORTER'S DIAMOND

Poland's Energy Diplomacy can be shown through a Porter's Diamond of national advantage. Using that model in the article, it can be demonstrated how Poland has been able to exploit its attributes to include factor conditions, demand conditions, supporting industries, and firm strategy to independent itself and introduce a counterstrategy against Russia and China's weaponization of energy diplomacy [1].

This study will analyse Poland's natural resources acquisition strategy and vision for energy diversification. Poland becoming dependent on one supplier, Russia, due to its lack of domestic natural resources and production capacity, is a threat to its energy security.

The article seeks to evaluate how Poland's energy diplomacy concentrated on energy diversification and innovation to become a regional economic power. This study will review the structured

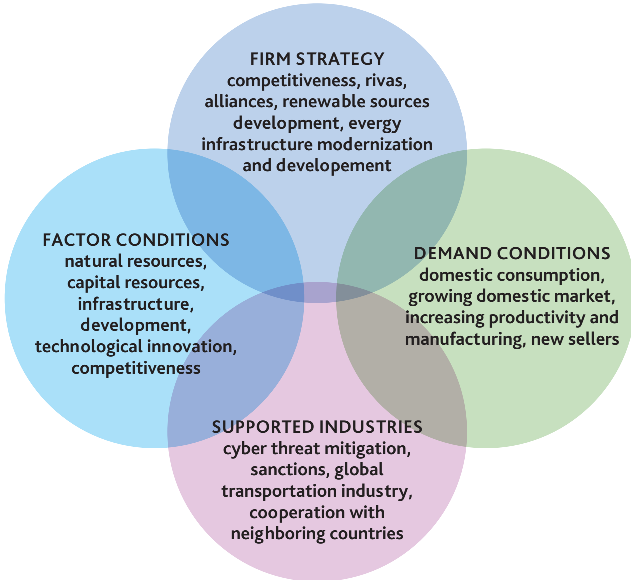


Figure 1. Porter's Diamond- Poland National Diamond

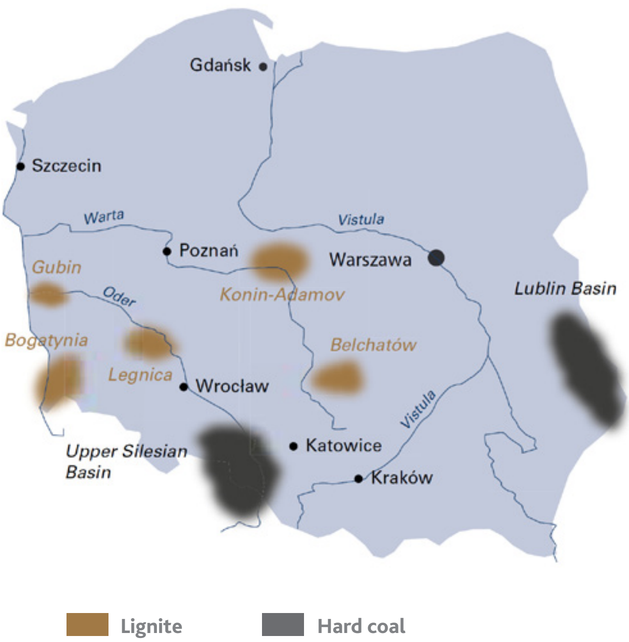
analysis of quantitative data related to Poland's energy consumption, natural resources, and international cooperation to meet its energy consumption needs. The results of this research found that although it has not manifested itself, Poland has reclused itself from its Russian energy dependency. Therefore, this article uses Poland as an example for diplomatic economic model for energy-dependent nations to develop national economic resiliency based on legal regulations, infrastructure development, and alliances contracts for the supply of natural resources. Finally, this study will explain Poland's Energy Diplomacy strategic risks to China's influence in the global energy market and explain the importance of the role of the U.S. alliance and how countries may mitigate the energy threat from Russia.

2.1 POLAND'S ENERGY SECURITY FACTOR CONDITIONS

Currently, the natural resource mix produced in Poland include 61% hard coal, 18% brown coal, 5% natural gas, 1% petroleum, 15% other [2]. Nowadays, the demand for natural resources in the Polish market is 40% hard coal, 11% brown coal, 14,8% natural gas, 24% oil, 9,7% others [3]. The data shows the overproduction of dirty energy sources and a deficit in natural gas and oil production. A map of coal basins in Poland shows that the primary energy sources, in particular, hard coal and brown coal, are located in the south. Bearing in mind such factors as environmental regulations, depletion of fossil fuel resources, and the unprofitability of Polish mines, they are a dubious advantage, and they will not grant Poland needed energy security in the future.

Statistics show that Polish domestic natural resources are not sufficient to cover consumers' needs and support Poland's prosperity. Taking into consideration the EU's industrial 4.0 energy transitions from coal to cleaner sources of energy, Poland is looking for alternative solutions that will replace dirty sources of fuel. However, domestic oil and gas deposits are minimal, and potential shale gas deposits have not yet been extracted. To cover this economic deficit, Poland must cooperate with gas exporters, such as Russian, to meet its national energy demands. Due to its geographical location and robust infrastructure, the Russian Federation has had a competitive advantage in providing Poland with its energy needs creating detrimental dependency.

Figure 2. Coal baisin in Poland

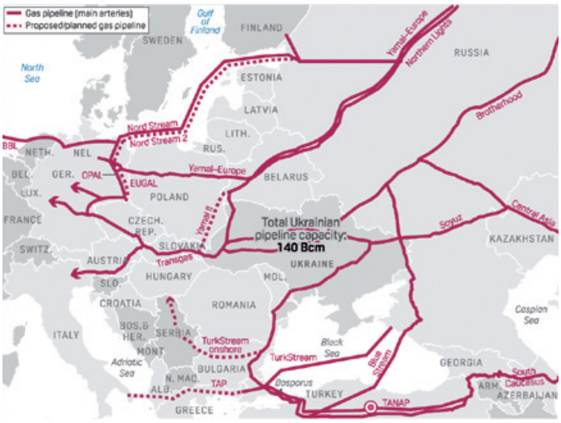


On the European market, Russia is considered a monolith in the field of gas extraction, production, and sales. The largest Russian company in this area is the state's own company Gazprom Public Joint Stock Company (PJSC), founded in 1989 with headquarters in Moscow. Taking into account that PJSC holds the world's largest gas reserves by company at 36,1tcm, which is 16% of the world's reserves, a 600bcm production capacity, the pipeline length of 172,600 km, and storage infrastructure, it is an indisputable regional leader in gas production [4]. Within the European market, Central European and Baltic members of the EU (CEB of EU) that were formerly part of the Eastern Bloc lack sufficient domestic natural resources and rely on long-term contracts for natural gas and oil from Russian-the leading regional supplier. However, dependence on one supplier is a threat to CEB of EU' energy security and thus is a risk to national economic stability.

It is imperative these countries maintain energy stability, develop industrial infrastructure, diversify suppliers, and seek new energy alliances to reduce dependence on a single supplier and avoid a serious threat to their respective economies. Until the collapse of the Soviet Union, nearly 100 percent of the former Easter Bloc Countries (EBC) imported gas and oil came from Russia, and EBCs did not treat issues affecting energy security as strategic concerns. Recent global security events, such as an increase in gas and oil prices, escalated and prolonged conflict in the Middle East, Russian invasion of Georgia in 2008, and the unlawful Russian seizure of Crimea in 2014 demonstrated the extreme dependency of CEB of EU' economies on Russian energy supply. It became clear that in the event of a conflict CEB of EU energy and national security would be endangered.

Today, import statistics continue to confirm both the CEB of EU and Western European countries are still heavily dependent on gas supplies from Russia. While the CEB of EU have taken several actions to become independent of Russian supplies, some Western European countries such as Germany do not see this as a threat. Despite the opposition to Russia's gas infrastructure expansion among most European countries and the

Figure 3. East to West Energy Pipelines



sanctions imposed by the U.S. on companies supporting the development of the Nordstream 2 (NS2) Russian gas pipeline, Germany continues to support this investment. Bearing in mind that with the launch of NS2 and the southern pipelines, the gas transport through the Brotherhood pipeline in Ukraine will be suspended, which will threaten this region of Europe and a key source of income for the Ukrainian economy.

Poland's LNG terminal in Świnoujście became the symbol of its energy independence. This strategic investment allowed for receiving liquefied natural gas by sea from virtually anywhere in the world. The gas terminal in Świnoujście is the largest LNG facility in northern central/eastern Europe. The European Regional Development Fund, financed its construction with 224 mil EUR, along with 5 mil EUR from the European Energy Program for expansion [5]. The current regasification capacity of the terminal is 5bcm per year. The terminal also has two cryogenic process LNG storage tanks with a capacity of 160,000 m^3 each. The expansion of the gas terminal is currently being completed and is being financed with 128 mil EUR from the EU's Infrastructure and Environment program. This investment will provide additional storage facilities and coastal infrastructure, increasing the regasification capability for the terminal by 50% to 7.5bcm per year. The expansion also includes the installation of the third cryogenic tank, construction of a transhipment installation for railways, and port facilities for improving the loading and unloading of LNG. Poland's investment indicates the seriousness of the Polish government to minimize the influence of Russian gas in its market. Furthermore, the development of the gas terminal is contributing to the diversification of Poland's natural gas supply sources, increasing its energy security, and serving as a regional gas hub that in the region supporting Ukraine, the Czech Republic, Slovakia, and the Baltic States.

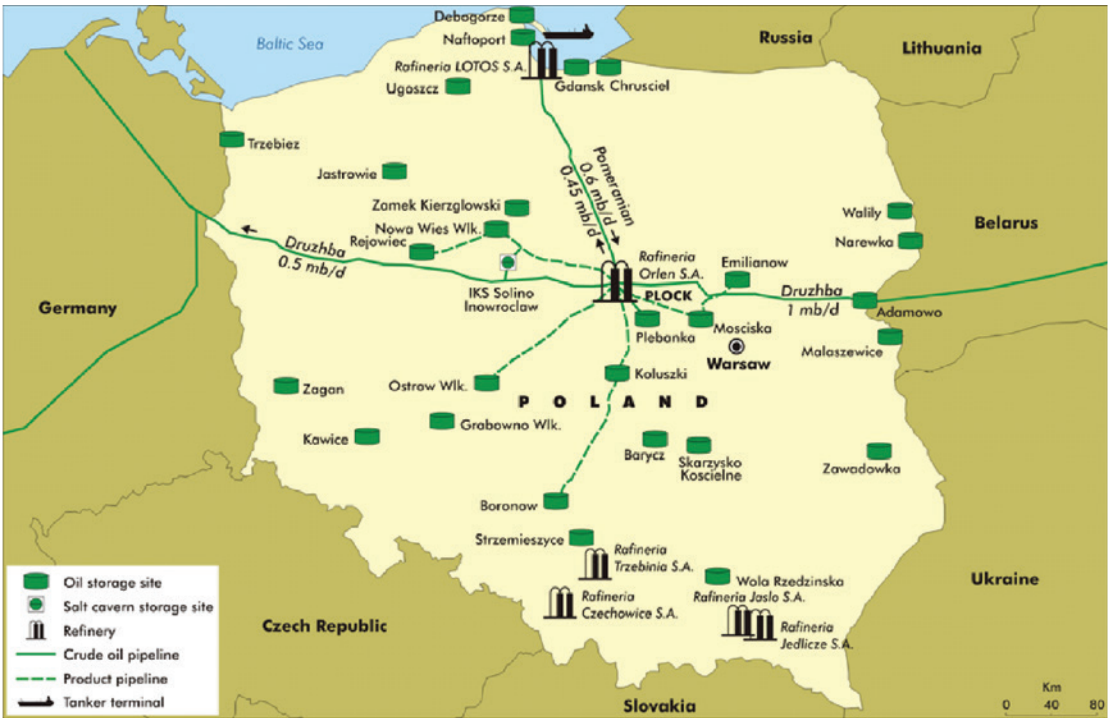
Another important sector for the Polish's energy security is the oil market with its supplies and transport and storage infrastructure. Similar to natural gas import, Poland purchases the most oil from Russia through the Brotherhood pipeline (Druzhba), which by 1996 accounted for 100% of imported oil. Keeping in mind the dependence on oil supplies from the East, the Polish government has taken steps to increase energy independence and security by expanding national infrastructure and signing contracts with other oil suppliers such as Nigeria, Great Britain, and Kazakhstan [6]. These activities increase the share of other oil suppliers for the Polish market, which has been growing for several years. The statistics confirm the fruitful result of these activities. In the article "Petrol and Natural Gas Market of the Visegrád Group Countries 1993–2016: Current State and Prospects " Kłaczyński says that "in 2015, Russia's share in the Polish oil market was 88%, the remaining 1.4% is from Saudi Arabia, 2.4% from domestic deposits, including wells in the Baltic Sea, and 1, 2% imported from Norway [7]." Due to the Polish government's strong position and related investment, as well as contracts for the supply of crude oil, changes in this sector are progressing quickly. In the third quarter of 2018, Russian crude oil fell to 67.2% of all imports [8]. In the first half of 2019, it was 63 percent of all crude oil imports. This policy resulted in the entry and strengthening of other suppliers on the Polish market, such as Saudi Arabia 15%, Nigeria 7%, Great Britain 5% as well as Kazakhstan and Norway 3% each of total Poland's crude oil imports [9].

One of the vital state energy security elements is oil transportation and storage infrastructure. In Poland, there are three oil terminals; the largest of them is Naftoport, located in Gdańsk. It is the only sea terminal for crude oil transhipment in Poland and the biggest national terminal for the transhipment of its refining products. Naftoport is also one of the largest oil transhipment terminals in the Baltic. Its handling and storage capacity amounts to 36Mt of oil and 4Mt of petroleum products per year [10]. In the maritime pier, transhipments of crude oil, gasoline, aviation fuel, diesel oil, heating oil, condensate, and components are carried out. In Poland, there are also two smaller terminals located in Gdynia and Szczecin. However, the sum of their capabilities in relation to Gdańsk allows the retention of only up to 5Mt. Moreover, these two terminals are not connected to the pipeline system, which limits their distribution capacity compared to Gdańsk. The Naftoport is an essential element of the oil supply logistics, supplying PKN Orlen and Grupa Lotos refineries with raw material. Its connection to the Pomeranian pipeline also enables the export of petroleum products by sea from Poland. In addition to crude oil and petroleum processed products pipelines, there are many oil storage areas in Poland that are supplied by land and rail, providing the opportunity to secure the market's needs with this type of energy resource. This infrastructure increases the possibilities of storing raw materials in the event of supply disruptions, which reduces the risk to the market.

2.2 POLAND'S ENERGY SECURITY DEMAND CONDITIONS

Domestic natural resources availability does not guarantee the state's energy security. A country needs transmission and storage infrastructure for current needs and keeping a reserve for economy mobilization needs. The annual Polish demand for natural gas is 18bcm per year. Poland imports 14bcm, of which 10bcm [11] is covered under contract with Gazprom [12]. Despite the significant investment in Świnoujście, 7.5 bcm per year of gas will not cover current Polish demand. In April 2019, Poland signed a grant agreement from the Cohesion Fund of 215 mil EUR to develop the Baltic Pipe. The pipeline is scheduled to be completed and operational in 2022. The goal of this project is to create a new independent gas supply corridor that connects sellers from Norway with Poland and its neighbours, and transport natural gas from Świnoujście to the Danish and Swedish markets [13].

Figure 4. Oil infrastructure in Poland



Both the investment in the Polish gas terminal and the Baltic Pipeline will benefit not only Poland, but also customers in neighbouring countries due to the energy cooperation. These projects are of particular importance for increasing security and diversifying the directions of natural gas supplies to the region. They are contributing to an increase in competition in the gas market and decrease the dependence on supplies from Russia. Similar to natural gas import, Poland purchases the most oil from Russia through the Brotherhood pipeline (Druzhba), which by 1996 accounted for 100% of imported oil. Keeping in mind the dependence on oil supplies from the East, the Polish government has taken steps to increase energy independence and security by expanding national infrastructure and signing contracts with other oil suppliers. These activities increase the share of other oil suppliers for the Polish market, which has been growing for several years. The statistics confirm the fruitful result of these activities.

In addition to Russia, China's Energy Diplomacy serves as an external risk and influence to Poland's energy security and national prosperity. The People's Republic of China (PRC) the challenge of instituting a more self-reliant energy security policy to sustain its economic growth and Russia's aggressive behaviour to control the CEB of EU's energy supply. The International Energy Agency projects China will be the largest global energy consumer, oil importer, and coal producer in the world by 2040 [14]. China's energy security policy is constrained because of its dependency on imported petroleum to support its total national energy consumption. Also:

- China remained the world's largest energy consumer, accounting for 24% of global energy consumption and contributing 34% of global energy demand growth in 2018 [15].
- In 2018, among fossil fuels, consumption growth was led by natural gas (+18%) and oil (+5.0%), while coal remained the dominant fuel. China's coal consumption as its share of total energy consumption in 2018 (58%) hit a historical low importing 54% of its coal from Australia, 31% from Indonesia, and 17% from Russia [16].

China's ability to synergize Sino-trade policies, foreign direct investment, and foreign energy-related acquisitions has been advantageous to supplant current international trade agreements and increase international Sino-business to divert world resources to China. Through its Shanghai Five negotiations and Sino-state owned international acquisitions, China has developed energy partnerships with Russia, Kazakhstan, Kyrgyzstan, Uzbekistan, and Tajikistan. In 2013, China's total $32B oil investment in Kazakhstan's Kashagan project to explore 12 oil fields of proven reserves of 390mts and the Kazakh-Chines oil pipeline construction demonstrates China's aggressive nature to outpace any international foreign investment in oil exploration [17]. The completion of the pipeline allowed Kazakhstan to double its oil exports to China, allowing China, in turn, to diversify its oil imports from Russia.

2.3 POLAND'S ENERGY SECURITY RELATED AND SUPPORTING INDUSTRIES

Russia is looking for new buyers and sees China as a key new gas market for sales growth. The Sino-Russia energy diplomatic efforts represent a more dichotomous environment. Institutionally, infrastructure development has served as the catalyst of the relationship. The Sino-Siberia pipeline is the most abundant gas project between the two countries [18]. The Siberia pipeline has allowed Russia to diversity itself from the European markets, in turn, benefitting China. Russia notes the threat to its gas interests in Europe. Some European countries, such as Estonia, Latvia, Lithuania, and Poland, are taking steps to become independent of Russian supplies. Also, the rapid production of gas and exports from Norway and the increase in imports by European countries Liquefied Natural Gas (LNG) from the U.S and Qatar, are causing Russia to look for new outlets. Therefore, Russia is expanding its pipeline infrastructure towards China and increasing the LNG production it intends to sell to countries where its pipelines do not reach. Russia is aware of losing customers on the European gas market and sees an opportunity for redirecting gas export to the China market. That is why it signed a sales contract for 30 years of 38bcm gas via the Power of Siberia pipeline in 2014 with the possibility of increasing by 6bcm in the next few years.

To support that investment, the seller uses the Czajandińskoye fields, and, in parallel, the company is building an 800-kilometer pipeline to the Kovykta fields [19].

The solidification of the Sino-Russia gas pipeline and Russian's pursuit in constructing the Nord Stream 2 (NS 2) gas pipeline along the Baltic Sea is a threat to Poland's energy security and others in the region. The NS2 capacity of 55bcm per year will allow Gazprom to directly export gas to the Western European market, bypassing Poland. Also, the launch of the pipeline detrimentally affects Ukraine's economy, which is dependent on Russia's gas throughput transport through Ukraine. This installation is a threat to both Ukraine and Poland transit routes that have been placed for years, bringing revenues and access to the resources. Underscoring NS2 is Gazprom's projected dominance in the European market. The Russia Federation wants to flood Europe with large amounts of gas at low prices to stop the construction of LNG intake ports along the region, and in its historically aggressive behaviour, impose increased gas prices to ensure that Russia's interests are secured.

Due to the U.S. sanctions imposed on companies supporting NS 2 construction, Poland has gained more time to prepare for this threat. The current contracts for gas supplies from Russia expire in 2022. There are discussions about whether to completely give up acquisition from this direction or if acquisition can be significantly reduced. The current Polish energy policy gives such opportunities because the expansion of the gas port in Świnoujście and Naftoport in Gdańsk is close to being completed, and the Baltic Pipe will be finalized in 2022, ensuring the increase in gas supplies.

Polish critical infrastructure is not free of hybrid threats. The increased risk is mainly associated with coastal projects such as the LNG terminal in Świnoujście and Naftoport in Gdańsk, whose safety is additionally affected by the proximity of the Kaliningrad Oblast. Another essential element of hybrid activity in the aspect of information to arouse panic by introducing false information or even a potential attack on critical infrastructure. Also, in the cybernetic aspect, one should take into account the possibility of the Russian influence on energy infrastructure to destabilize the supplies of competing companies or delays in the construction of new investment.

2.4 POLAND'S ENERGY SECURITY, A STAPLE OF DEFIANCE, FIRM'S STRATEGY

For several decades, issues affecting energy security were not treated by Poland as strategic concerns. Until the collapse of the Eastern Bloc, nearly 100% of the country's imported energy resources came from Russia. It was only during the global political changes and the significant increase in gas and oil prices that a broad discussion began. The peak was in 2008 when oil prices soared, and the ongoing conflict in the Middle East and the Russian invasion in Georgia did not anticipate rapid stabilization in this sector. Another key event is the hybrid war between Russia and Ukraine. After the unlawful seizure of Crimea in 2014 by Russia, it became clear that the list of potential hybrid threats for Central European countries is much greater than the "standard" blackmail on the part of Gazprom regarding gas prices and supplies. As a result, Ukraine lost its ability to import gas and oil from Russia overnight, which resulted in higher commodity prices. These facts show how much the Polish economy depends on Russian raw materials. In the event of a conflict between countries, the security of energy resources will not be guaranteed.

2.4.1 POLAND ENERGY ALLIANCES AND POLICY

Developing and seeking new alliances is aimed at increasing the security of the State and strengthen its position in the global environment. The benefits of a partnership are in the sharing of goods a country has in exchange for the resources a country needs. Poland is a member of the V4 Visegrad Group, founded in 1993, whose aim is to improve and strengthen the position of Poland, the Czech Republic, Slovakia, and Hungary countries in cooperation with the EU and NATO in various areas in this field of energy security. Kłaczyński, in the column "Gasoline and Natural gas market of the Visegrad Group 1993–2016: current state and prospects," articulates that "Among the V4 countries, Poland has the greatest potential for natural gas and oil production." The author also presents the records of resources that place Poland as a leader among the V4 member states [20]. It would seem that Poland does not need allies and can rely on domestic producers PKN Orlen and Lotos. However, nothing could be more wrong. Local companies are too small to be independent on a global scale and ensure the energy security of the State. Also, current domestic gas and oil production is insufficient to cover Poland's economic needs. That is why Poland should look for new local alliances that will increase security in this area. Considering partnerships, one should also keep in mind suppliers of natural resources from around the World. The negotiated long-term contracts for reasonable price terms of diversified supply direction can reduce the potential risk of supply chain disruptions.

Renewable energy is another energy sector that has an impact on national security. Following energy policy, Poland also diversifies the energy mix towards renewable energy sources. According to EU requirements, the share of this sector in the final energy consumption of the State should reach 15% in 2020. In Poland, wind energy is the fastest-growing branch of renewable sources of energy, then solid biomass, but the share of hydropower is not widely used. Individual customers mainly invest in solar energy and heat pumps in households. Development and increasing the use of renewable energy sources contribute to the diversification of the sources and reduce dependence on other imported conventional sources such as natural gas or oil. Also, they are reducing the use of coal that pollutes the environment.

2.4.2 MITIGATION OF RISK FOR THE POLISH ENERGY SECTOR

The development of infrastructure is an essential requirement for keeping the state economy on a path of long-term economic growth. Poland, using its own and EU funds, has made significant progress in modernizing energy infrastructure over the past 20 years [21]. The expansion of the energy transport and storage sector helps to diversify the directions, supply sources, and types of fuels used. However, due to the transmission system and currently binding contracts for oil and gas supplies from Russia, this still poses a threat to Poland's energy security.

It is indisputable that the State's energy security policy is significant, and measures should be taken to reduce the dependence on supplies from a single source, which increases independence in the event of reducing supplies or an increase in energy prices. To become independent from the eastern supply of energy resources and increase energy security, the current Polish investment plans through 2030 provide for a significant investment in storage and transmission infrastructure. Also, this threat could be reduced by implementing an appropriate energy strategy, diversifying suppliers, developing alternative energy sources, modernizing, and developing refineries.

2. CONCLUSION

Based on the above analysis of natural resources and energy-transportation infrastructure, using the Porter's diamond model, it can be concluded that competition on the Polish energy market is highly dependent on Russian energy supplies. Many companies are entering the market to replace Poland's leading supplier, Gazprom. The Polish government has instituted innovative industrial policies, infrastructure development, and international financing in order to introduce renewable energy and energy diversification to improve its national security and prosperity. Polish natural gas and oil demand are growing. However, due to competitiveness on the market, it is possible to minimize the dependence of supplies from Russia while maintaining good price resources. The fact is that due to the right policy and investments, this national security concern is decreasing. Through international cooperation and economic assistance, other global actors such as the U.S. and Europe can oppress Russia energy leadership in Europe and China's aggressive behaviour to maintain global energy bargaining power and prosperity

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