



**NATO ENERGY SECURITY
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ENERGY HIGHLIGHTS



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 brought¹ 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 im-

port 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 lobbying 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 fuel⁶. 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 cities⁷. 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, foment 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

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.

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

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 possess 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 shut-

down 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 plants⁹ [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 Zaporizhzhya 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 actions¹⁰, 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 destruction 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 install¹¹. An attack on the energy grid thus can cause cascading effects across all sectors of critical infrastructure that require electric power with potentially devastating effects on modern economic activity, national security and well being of society.

3.1. SEIZURE OF ENERGY ASSETS

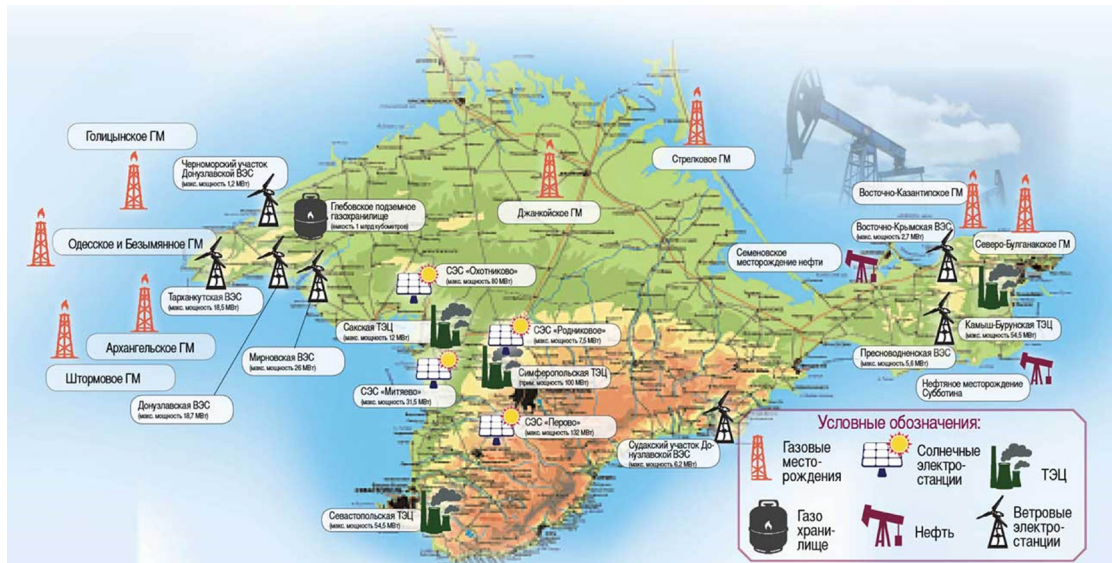
During its invasion of Crimea, Russia promptly and purposefully captured energy infrastructure, resulting in Russian control over energy companies in Crimea. Crimean administrative buildings were occupied and orders for re-subordination of all energy facilities were given from there [32, 33]. At the 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 function 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.

Nevertheless, 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 Vuhlehirsk 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 Chornomorneftgaz, 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.

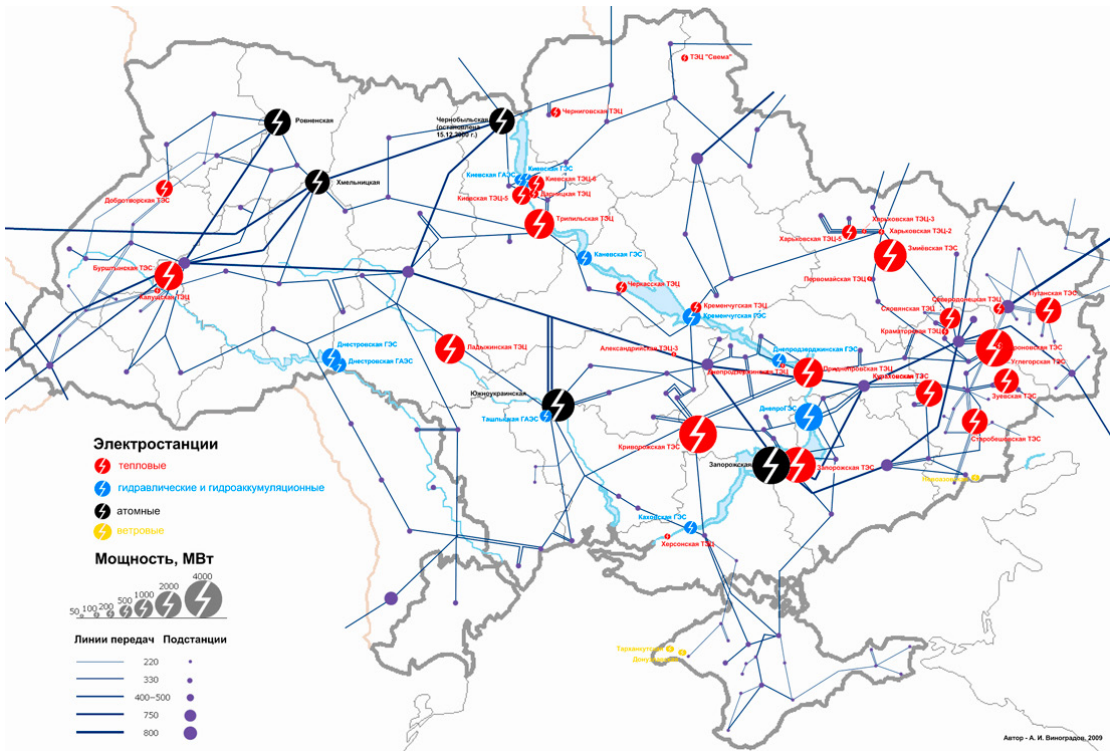
In 2014 the fighting zone included also the Slovianska TPP in Sloviansk city (0.88 GW).

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.

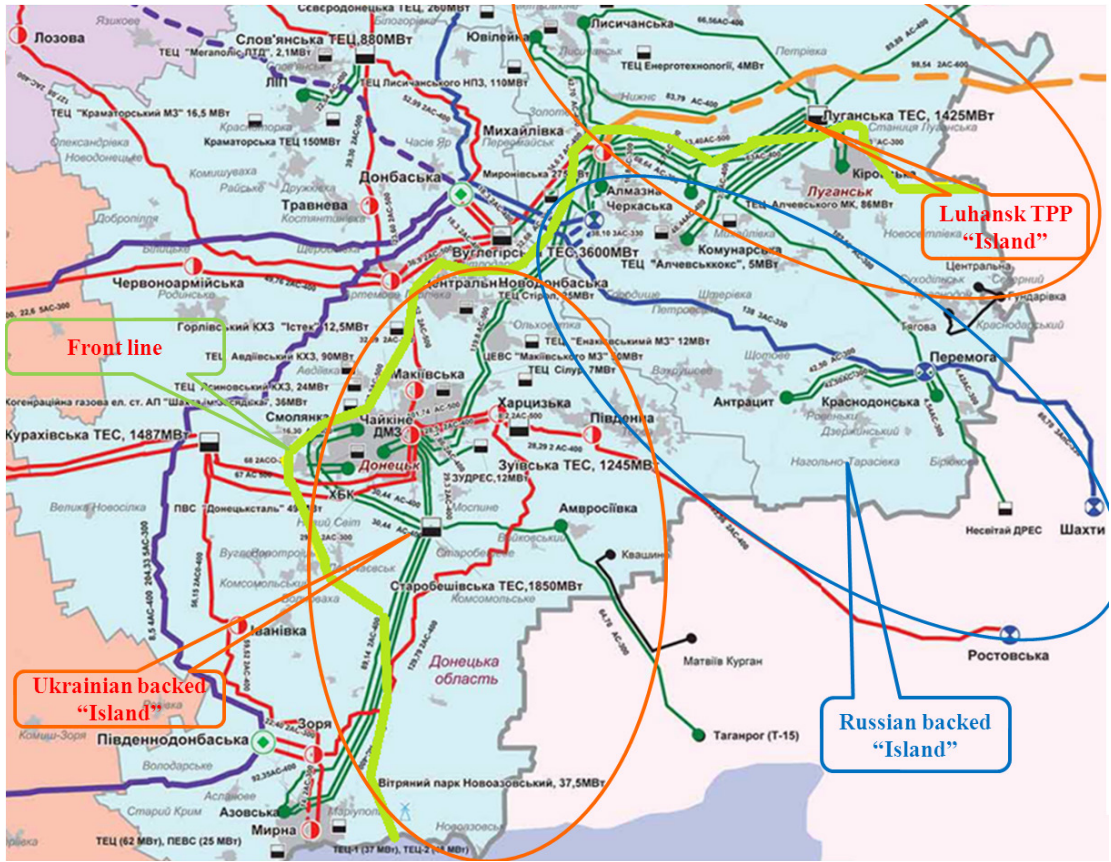


¹³ The damage to the Luhansk TPP was the most critical for Ukrainian government because it is the only source of electricity supply for the whole Luhansk region. Currently the Luhansk TPP (fueled by anthracite type coal) is the heart of the 'Luhansk TPP island' (fig. 3) that functions separately (is 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).	561, 562, 563, 564, 655, 566
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-dyversiiia-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-Novoposkov, Orenburg-Novoposkov, Urengoy-Novoposkov, 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-Mariupol¹⁶ 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 service¹⁷. 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>
МАРИУПОЛЬ, 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 газу в Маріуполь і Бердянськ тільки що відновлені – Яценюк.
<https://economics.unian.net/energetics/1089224-postavki-gaza-v-mariupol-i-berdjansk-tolko-chto-vosstanovleniyi-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 INFRASTRUCTURE

For the entire duration of the military operations in Donbas, blocking and destruction of coal transportation routes to Ukrainian TPPs was re-

peatedly 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 mines¹⁸, 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 time¹⁹. 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 activists 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 pri-

mary 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 Donetskoblennerho, 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 2011²⁵ 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.

²⁴ Sandworm and SCADA, Trend Micro <http://blog.trendmicro.com/sandworm-and-scada/> October 16, 2014

²⁵ 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

²⁶ 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

²⁸ "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]:

- adversary's use of social engineering methods (malware hidden in emails) to target employees and gain a foothold on the network;
- once a presence on the network was established the placement of BlackEnergy malware exploitation tool for reconnaissance and privilege 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 affected 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 disrupting 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 Industroyer³¹/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 Ukratnafta-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 energy 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, degradation 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 performance.

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 mitigate 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
<p>Threat to stop the operation of the Unified Energy System of Ukraine (due to lack of fuel (coal, natural gas) for power generation)</p> <p>Stopping power supply (damage to TPP and transformer substations, gas pipelines' disruption)</p> <p>Termination of water supply to cities due to pumping stations breakdowns (damage to electrical networks, pipelines, obstructing repairs)</p> <p>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"</p>	<p>Seizure of energy production facilities and infrastructure (industry, resources, infrastructure)</p> <p>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.)</p> <p>Seizure of Ukrainian state coal mines and sales of seized coal to Ukraine under the guise of Russian contracts</p> <p>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</p>	<p>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)</p> <p>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)</p> <p>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)</p> <p>Disruption of the energy sector just when the adversary does something they know will draw target nation's response.</p>	<p>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)</p> <p>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</p> <p>Impression given to citizens that their Government is incompetent in insuring their well-being.</p>

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 kinetic 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 electricity to citizens) on the industrial control systems used to remotely monitor 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 Russia³⁶. 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 began with targeted attacks on governments accounting software and spreading to major corporations like Maersk Shipping lines resulting in losses of hundreds of millions Euro.³⁷

The Russian information, propaganda and cyber campaigns were 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 succeeded.

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.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 "Ukr-energo" 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 deepwater 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.000gy0k6y1eb3f6ixg1zhh0k722b>

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 region⁴⁴ [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 businesses⁴⁵. 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 capacity⁴⁶.

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 territory) 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 Starobeshivskaya 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 Ukrspilav", 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"				
Shheglövs'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'kyi 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'kyi 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'kyi district, Heorhiyevka village
Cherkas'ka mine	G	E	13,31	Luhans'k region, Slov"yanoserbs'kyi district, Zymohir"ya-1 city
n.a. Artema mine	L	E	75,64	Luhans'k region, Pereval's'kyi 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'kyi district, Fashchivka urban settlement
n.a. XIX z"izdu KPRS mine	G	E	295,62	Luhans'k region, Lutuhyns'kyi 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 "Donbasanratsyt"				
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 mine	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 "Anratsyt"				
Partyzans'ka mine	A	E	400,01	Luhans'k region, Anratsyt city, Kripens'kyi urban settlement
Kripens'ka mine	A	E	1656,70	Luhans'k region, Anratsyt city, Kripens'kyi urban settlement
Komsomol's'ka mine	A	E		Luhans'k region, Anratsyt city, Dubivs'kyi urban settlement
SOE "Roven'kyanratsyt"				
n.a. F.E.Dzerzhyns'kohu 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'kyi urban settlement
n.a. V.V.Vakhrusheva mine	A	E	1121,40	Luhans'k region, Roven'ky city, Yasenivs'kyi urban settlement
N 81 Kyivs'ka mine	A	E	438,91	Luhans'k region, Roven'ky city
SOE "Sverdlovanratsyt"				
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
Tsentrosopilka mine	A	E	654,91	Luhans'k region, Sverdlovs'k city, Komsomol's'kyi 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'kyi district, Bilorichens'kyi 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.

UKRTRANS GAS 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
Mariupol 1	Amvrosiivcki
Mariupol 2	Belojarovskij
Mariupolck	Horlivka 1
Pervomajsk	Horlivka 2
Volodarskogo	Stirol
Malinovka	Khartsyzk
Manhush	Zuhres 1
Yalta	Zuhres 2
Dzerzhinsky	Ilovaik
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

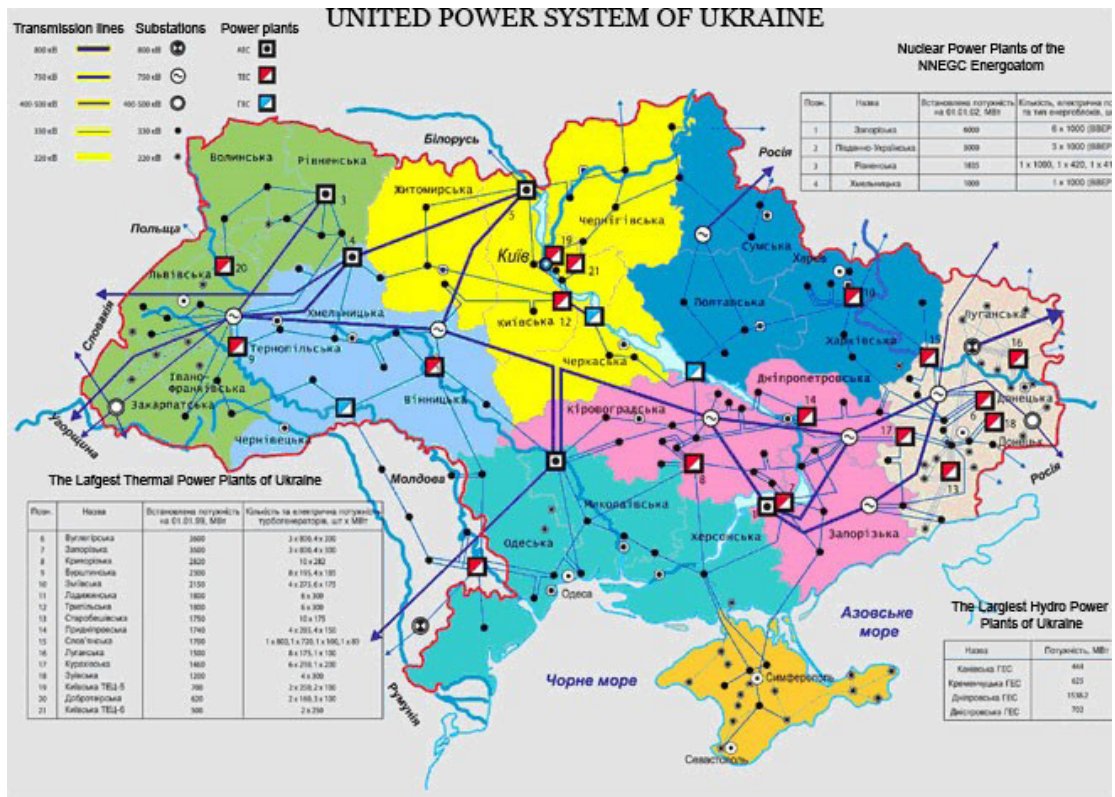
On Ukrainian controlled territory	On territory not controlled by Ukraine
Gas distribution stations in Luhansk region	
Krymske	Izvaryne
Luhansk	Krasnodon 2
Popasna	Antratsyt
Ukraina	Yasynivka
Artyoma	Rovenky
Pobeda	Blahivka
Rodina	Daryevka
Rascvet	Dyakove
Schast'e	Sverdlovsk
Suvorova	Rovenkovski
Artyoma	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 subsystems 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)	<p>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.</p> <p>Due to the shelling, electricity cables had been destroyed in government-controlled Trokhizbenka, Kriakivka, Orikhove, Lobachevo, Lopaskine, Gravove, Orikhove, Krymske, Novozvanivka and Troitske.</p>	unknown	79
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 (<i>"DLPR"-controlled</i>).	80
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).	81
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 (<i>"DPR"-controlled</i>).	82
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 (<i>"DPR"-controlled</i>).	83
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.	84
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	85

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 (" <i>LPR</i> "-controlled).	86
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 (" <i>DLPR</i> "-controlled).	87
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	88
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 (" <i>DLPR</i> "-controlled).	89
19.07.2016	Yasynuvata (" <i>DPR</i> "-controlled, 16 km north-east of Donetsk)	<p>The electric power lines near Yasynuvata were damaged due to shelling, causing the local water filtration station to stop operating.</p> <p>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.</p>	unknown	90
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 " <i>DPR</i> "-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 (" <i>DLPR</i> "-controlled).	91
30.07.2016	Avdiivka (17 km north of Donetsk)	An electricity pole had been snapped in half and had fallen	unknown	92

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	93
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 (<i>"LPR"-controlled</i>).	94
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.	95
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 (<i>"LPR"-controlled</i>).	96
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 (<i>"DPR"-controlled</i>).	97
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 (<i>"DPR"-controlled</i>).	98
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 (<i>"DLPR"-controlled</i>).	99
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 (<i>"DLPR"-controlled</i>).	100

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	101
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	102
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	103
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	104
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	105
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	106
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	107

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.	<i>Shelling from "DPR"-controlled territory</i>	108
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	109
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	110
06.03.2016	Petrovskiyi 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 Petrovskiyi 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	111
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.	<i>Shelling from "DPR"-controlled territory</i>	112
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	113

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	114
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	115
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	116
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	117
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 <i>Voda Donbassa</i> 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	118

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

*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/
 Khmelnytsky Nuclear Power Plant (KhNPP) - http://www.energoatom.kiev.ua/en/separated/npp_khmelnyska/

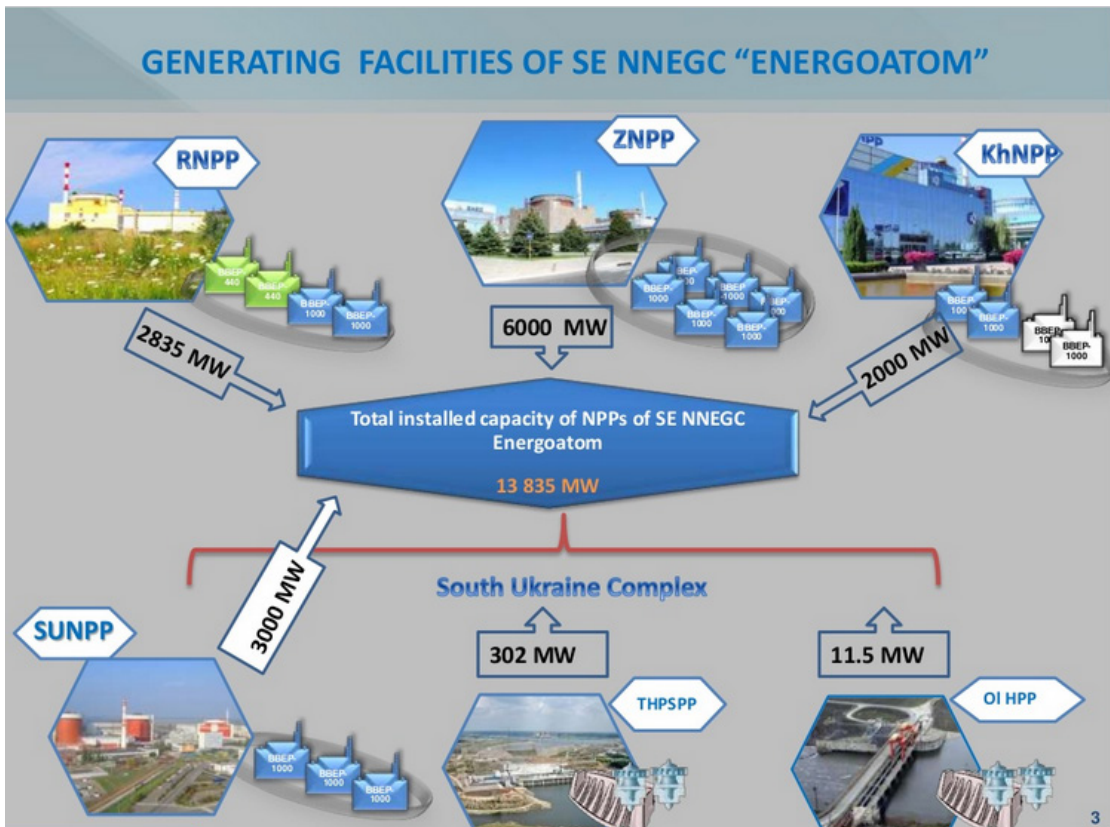
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Appendix 10. Basic countermeasures (on the part of Ukraine) to the hybrid aggression of Russia

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 infra-

structure and priorities of security, including:

- to comprehensively comprehend the legal basis of the critical infrastructure, securing the systems of state control over security;
- to strengthen the protection of critical infrastructure, including energy and transport;
- to establish cooperation between different entities to protect critical infrastructure, develop public-private partnership in the field of disaster prevention and response;
- 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;
- to prevent man-made accidents and prompt an adequate response to them, localise and minimise their consequences;
- 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 counter-intelligence 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 cybersecurity 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 Ukraine <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 SSSU – 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 – Industrial 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

SDDL – 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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