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Nuclear safety in crisis regions

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Summary

The use of nuclear energy demands extensive institutional and material infrastructure upon a foundation of stable intrastate conditions and interstate relations. This being the case, inter-, intra- or substate conflicts can result in catastrophic accidents, either deliberately or unintentionally. If there are nuclear facilities located in a crisis region, the risk of a nuclear disaster is markedly heightened. This can be explained not only in terms of the strategic relevance of the energy supply in military conflicts, but also the increased accident risks and hazards arising from collateral damage, as well as the erosion of the safety culture and institutional control in crisis regions with a nuclear infrastructure. Even just the escalation of a political dispute or the persistence of low-intensity conflicts can make it generally more difficult and complex to maintain nuclear safety, if intrastate safety mechanisms come under strain or even fail as a result.

So far no instance of military escalation, past or present, has led to an accident in a civil nuclear facility. Nevertheless, questions are clearly raised about the vulnerability of nuclear facilities in crisis regions and the risks associated with this vulnerability. Despite the potentially far-reaching consequences, too little attention is currently being paid to the linkage between intra- and interstate conflicts and the safety of nuclear facilities in crisis regions. The aim of the research presented here was to explore this theme and, after laying the groundwork in this manner, to raise awareness among policy-makers and the wider public. In that endeavour, the document draws on current and historical examples and addresses various factors pertaining to nuclear safety in crisis regions and the possible consequences if it were deliberately or accidentally compromised. In this context the escalation of conflicts in the Ukraine is a particular focus.

The first part of the report begins with a systematic look at the link between crisis regions and/or conflicts and nuclear safety. The various impact pathways relating to nuclear facility safety and the associated risks are described in relation to potential hazards induced by crises and wars.

A nuclear facility can itself become a theatre of combat operations. This study considers aspects including the misappropriation of radioactive inventory, the possibility of acts of sabotage by inside perpetrators, the penetration of unauthorised intruders into the facility, or an attack from outside it. A particular possibility during military conflicts is that the safety of nuclear facilities may be compromised unintentionally or that “collateral” damage may reach a scale hazardous to safety, either directly or by error propagation, whether or not this is the combatants’ intention. An especially probable and relevant concern in this context is an interruption of the facility’s external power supply or an attack on the power grid, so that electricity has to be supplied by the facility’s own emergency power system.

Over and above direct interference with nuclear facilities, in crisis situations there can also be substantial disruption of institutional control, the safety culture, access to facilities, to information or to international expertise, as well as the availability of specialist personnel. In addition, the physical delivery of fuel, expendable and replacement parts, the technical and scientific support of the nuclear infrastructure, and the training of personnel can be affected. This is a particular problem when manufacturers and suppliers are located abroad, possibly in a country that has become a party to the conflict, as is currently the case between Ukraine and Russia. A state’s fundamental ability to control a nuclear accident and its consequences, which is one of the fundamental requirements for safe operation of a facility, can be weakened or lost altogether.

How such additional risks to nuclear safety should be quantified remains largely unclear; in the context of safety studies, they are either categorised as too improbable or are not dealt with at all. Indeed, an obvious conclusion is that all deliberations about safety concepts for nuclear power

plants and nuclear facilities to date have largely steered clear of thinking about military or other armed conflicts. It seems as if the parties to conflicts are assumed to be under some kind of "taboo" not to carry out any intentional attack for the purpose of releasing the radioactive inventory.

In the second part, selected examples of different crisis regions, both historical and contemporary, are described and set in the context of a possible hazard to nuclear safety. The incidents discussed include Iran's bombardment of the Iraqi reactor in the course of the Iran/Iraq wars and Israel's threatened preventive military strike against Iranian nuclear facilities. A less well-known case is the example of the Metsamor reactor in Armenia, which illustrates how diverse the links between conflicts and possible impacts on facility safety can be. Military conflicts over many years and the resulting economic hardship and political calculus are having indirect impacts on the risks of this ageing and, moreover, severely earthquake-prone reactor – a volatile combination of factors for nuclear safety.

Further examples are Pakistan with its unstable situation in the regions bordering India and Afghanistan; the civil war in former Yugoslavia with the military threats to the Krško nuclear power plant; and the impacts on the nuclear infrastructure resulting from the non-violent but nevertheless far from problem-free partition of Czechoslovakia after the fall of the Iron Curtain. Finally, the complex of problems surrounding embarking countries with weak state infrastructures in conjunction with their new reactor construction plans is given a cursory glance but is not examined in depth in the context discussed here.

As a thematic focal point, Ukraine is examined more closely as a crisis region. This case example is not just representative of the changing global safety architecture and the shift from classic military conflict pursued by state parties towards asymmetric warfare with state involvement (hybrid warfare); the Ukraine conflict gives further cause for concern because, despite the current low-key media coverage, the crisis has not ceased to exist and a future escalation cannot be ruled out.

An essential component of the project was the survey conducted with interview partners who are currently or were formerly engaged in the field of nuclear safety in Ukraine. Those questioned were technical experts, journalists and members of NGOs. The interview partners who were selected for the survey and consented to participate have long been dealing with the theme of nuclear safety or domestic and energy policy in Ukraine.

Because of the volume of information obtained in the interviews, within the scope of the present report it is only possible to reprint extracts from the interviews which permit an insight into the current status of Ukraine's nuclear infrastructure. The themes include the links between nuclear safety and the political and legal settings, the status of the radioactive inventory, the detrimental effects of the ongoing civil war on the specialist personnel situation, the evaluation of incidents with a bearing on safety, and general (subjective) comments on the political and social situation in Ukraine. The interview responses, of which the content is summarised in Section 5.3, reflect the opinions of the experts questioned only.

The example of Ukraine shows how fragile the originally stable conditions in a country within Europe can become. The Ukraine conflict is also representative of how similar situations can occur in other regions in the world, even in those which were previously considered stable.

The objective of this paper was to give an overview of the diverse linkages between intra- and interstate conflicts and nuclear safety, and to point up how fragile the nuclear infrastructure can become under such dynamic conditions. In a situation of political and military crisis in conjunction with a poor economic situation, and all the more under conditions of armed conflict, there can be an insidious yet massive erosion of the entire nuclear safety network, and hence a commensurate heightening of the risk of a serious accident.

Within the scope of the project it has not been possible to deal with many aspects of the theme in comprehensive depth. However, the present document can serve as a starting point for a future, more in-depth study and may help to raise awareness regarding the risks of nuclear energy.

Acknowledgement

We consider nuclear safety in crisis regions to be a theme of extraordinary importance, particularly in the times we live in and in view of the conflict in Ukraine. Without the financial support of the Legacy for the Future Foundation (*Stiftung Zukunftserbe*) our research into this theme would not have been possible.

1. Introduction

The peaceful use of nuclear energy that commenced in the 1950s has already manifested its high risk potential on a number of occasions. The serious accidents that have occurred in nuclear facilities in the intervening period have given rise to broad-scale as well as transboundary repercussions, with massive adverse impacts on the affected people and the environment which persist to this day. All accidents so far have occurred under the conditions of peacetime society and were caused by human error or natural disasters. So far military escalations have not led to an accident in a civil nuclear facility or influenced the accident sequence. Nevertheless, in light of the increase in military conflicts, there are fundamental questions to be raised about the vulnerability of nuclear facilities in crisis regions as well as the resulting risks of a nuclear disaster.

Particularly in recent years, the number of violent conflicts and hence the numbers of fatalities and casualties have risen. State and intrastate conflicts are those which involve states and their organisations. But conflicts can also be fought out between non-state armed groupings (e.g. between IS and Kurdish militias). Conflicts can go through phases of low intensity and nevertheless have massive social and economic impacts on civil society and its institutions. Equally, they can escalate to the dimensions of a broad-scale military conflict. In Europe the episodes that aroused greatest concern in recent decades were the civil war in Yugoslavia and the escalation of the conflict in Ukraine. Particularly in Ukraine, there is potential for the unresolved conflict to escalate further at any time.

If there are nuclear facilities located in a crisis region, the risk of a nuclear disaster is markedly heightened, not only as a result of intentional actions but also of accidental events and unintended consequences, and by erosion of the safety culture and institutional control. Time and time again it has emerged that even under framework conditions of political stability, safety deficiencies can remain undetected and sometimes documentation can be falsified.[1] In a situation of political and military crisis in conjunction with a poor economic situation, and all the more under conditions of armed conflict, such “harmless” cases and error factors can result in a massive erosion of the entire network of nuclear safety, and hence a commensurate heightening of the risk of a serious accident.

The present project documentation refers to current and historical examples to address the various factors and possible consequences of a deliberate or accidental compromising of nuclear safety in crisis regions. No political analysis is carried out into the emergence of these different conflicts; instead, a spotlight is turned on the multiplicity of their impacts on nuclear safety. The current conflict in Ukraine is dealt with in depth. This case example is not only representative of the changing global safety architecture and the shift from classic military conflicts pursued by state government parties towards asymmetric warfare with state involvement (hybrid warfare) – the Ukraine conflict gives as much cause for concern as ever. Despite the low-key media coverage, the crisis has not ceased to exist and escalation cannot be ruled out.

An essential component of the project was the survey conducted with interview partners who are currently or were formerly engaged in the field of nuclear safety in Ukraine. Those questioned were technical experts, journalists and members of NGOs. The interview partners who were selected for the survey and consented to participate have long been dealing with the theme of nuclear safety or domestic and energy policy in Ukraine.

Because of the volume of information obtained in the interviews, within the scope of the present report it is only possible to reprint extracts from the interviews which permit an insight into the

[1] Such as the documents falsified by Areva concerning tests on forged metal parts from the Le Creusot factory http://de.euronews.com/2016/05/03/franzoesischer-atomkonzern-areva-soll-zertifikate-gefaelscht-haben

current status of Ukraine's nuclear infrastructure. The themes include the links between nuclear safety and the political and legal settings, the status of the radioactive inventory, the detrimental effects of the ongoing civil war on the specialist personnel situation, the evaluation of incidents with a bearing on safety, and general (subjective) comments on the political and social situation in Ukraine. The interview responses, of which the content is summarised in Section 5.3, reflect the opinions of the experts questioned only.

The example of Ukraine shows how fragile the originally stable conditions in a country within Europe can become. Nor is it an isolated case in Europe, as was shown by the civil war in former Yugoslavia more than twenty years ago (Section 3.3.1). These conflicts make it clear that similar situations can occur unexpectedly in other regions of the world, even in those which are currently considered stable. Further examples in Chapter 3 show the multiplicity of impacts on nuclear safety that can arise from conflicts. In particular, the example of Armenia is instructive and would likewise merit in-depth study because here, too, conflicts have intensified again in recent years (Section 3.2.2).

Although a few experts and politicians have drawn attention to these kinds of risks and their grave nature (Deutsche Welle 2014; Kovynev 2015; DWN 2014), political and social debate on this theme seems to remain below the radar of public perception. This document gives an overview of the various influencing factors and aspects of conflicts as they affect nuclear safety, and points up how fragile the nuclear infrastructure can be under such dynamic conditions. The subject matter cannot be dealt with in comprehensive depth in many respects; nevertheless, this document provides a starting point for a future, more in-depth study in future and as a contribution to raising awareness about the risks of nuclear energy.

2. Nuclear power plants in crisis regions

A precise definition of the characteristics of a crisis region or the distinctions in terminology between crisis, war and conflict are beyond the remit of this study. The definitions used here, where needed, are taken from the Conflict Barometer (HIIK 2016) of the Heidelberg Institute for International Conflict Research (Section 3.1). The term "crisis region" which is used hereafter in a general sense refers to a wide array of non-violent and violent, interstate, intrastate, substate and state-forming conflicts: it includes conflict regions, civil wars, regional conflicts, military conflicts, limited wars, from uprisings and guerrilla regions to phenomena in the aftermath of violent conflicts with repercussions for the state's infrastructure and administration, e.g. violent changeovers of power, decayed and decaying states, failed states, and cases of fragile statehood.

Every specification and class of conflict entails very different causes, actors and resources for the given conflict, which need to be examined more closely for the purposes of a case-specific study. In this study, however, such differentiations only matter insofar as they can have different impacts on nuclear facilities. For example, a military conflict with heavy artillery in the direct vicinity of a nuclear power plant poses different dangers than fragile statehood in the aftermath of a violent change of government, perhaps with an ensuing drop in competence due to the removal of politically disagreeable experts. Differentiations can also be helpful for the identification of current and historical case examples in which nuclear facilities located in a "crisis region" were affected.

It is obvious that ensuring nuclear safety becomes a challenge under the conditions of a military conflict. Even just the escalation of a political dispute or the persistence of low-intensity conflicts can make it more difficult and complex to maintain nuclear safety generally if intrastate safety mechanisms come under strain or even fail as a consequence. Nuclear safety in this context refers not only to the safe operation of reactors and their technical infrastructure but also to the entire supply and disposal chain, including the necessary transportation and, an especially relevant consideration, the interim storage facilities for highly radioactive wastes. For interim storage the spent fuel elements are removed from the reactor but must continue to be stored above ground and kept secure. Planning and implementing the final storage of highly radioactive wastes is extremely complex, and has not currently been put into practice in any country in the world, even under peaceful conditions.

Thinking in terms of the safety of a nuclear facility, possible impacts on a nuclear facility in a crisis region can be broken down roughly as follows:

- In the event of a military conflict, a nuclear facility can itself become a theatre of combat operations or can be affected inadvertently by combat operations on neighbouring territory.
- A nuclear facility can be sabotaged or attacked from within or from outside.
- The necessary technical infrastructure (such as the connection to the external mains power grid or the cooling water supply) can be compromised.
- The extended institutional and material safety infrastructure, consisting of operators, authorities, manufacturers, suppliers and stable intrastate conditions that allow for criticism and public control, can be compromised.
- (Emergency) management efforts can be made significantly more difficult in the event of a nuclear accident.

Making strict distinctions between the various categories, e.g. between a military assault and a sabotage attack, is not always possible and not absolutely necessary for the purposes of the analysis carried out here.

2.1. Military conflicts

A direct military assault on a nuclear reactor that has already been commissioned and contains highly radioactive spent fuel elements has never yet taken place. There was, however, at least one situation during the war in Yugoslavia in which a warplane was flown over a reactor and the possibility of its destruction used as a deterrent signal (see Section 3.3.1). And during the Cold War, thought was given to the eventuality that nuclear power plants could become the target of military conflicts. There is discussion in (Ramberg 1980) of the radiological and strategic implications for a range of potential crisis regions under the then-prevailing conditions of Cold War global politics. Today the deployment of tactical and strategic nuclear weapons for the destruction of nuclear facilities is improbable, while tactical ideas such as deploying the radioactive inventory as a mine to influence enemy troop manoeuvres may also be viewed as somewhat exotic.

In respect of the feasibility of kinetic attacks from outside the facility, it was concluded some time ago by (Ramberg 1980) that a power plant would not withstand direct bombardment with bombs or modern artillery missiles. The dynamic development of military technology exerts an intensifying effect. The weapons systems deployed in military conflicts have become more accurate, more mobile and more powerful. Precision-guided bunker-breaking munitions can effortlessly penetrate several metres of steel-reinforced concrete and thick steel walls, while even portable weapon systems have gained considerably in penetrative force. Further innovations are taking place in the development of unmanned and autonomous weapon systems with constantly improving payloads.

The possibility that nuclear power plants or other nuclear facilities like storage pools for spent fuel elements could be destroyed in order to use the radioactive inventory itself as a weapon is naturally contingent upon one party to the conflict having a premeditated motive. This is rather improbable, except in very far-reaching military conflicts, but cannot be ruled out entirely. In a military conflict, nuclear power plants are already tactical and strategic targets for the more basic reasons that they contribute to the energy supply and that damaging or destroying them can result in massive destabilisation of a country's supply system and logistics. Another possibility is that of one party merely threatening to bombard a power plant, although this – like the scenario of using nuclear weapons as deterrents – turns into a psychological game (the game of "chicken" or the "prisoner's dilemma" (Zagare 2013)) which can also end in a nuclear disaster.

In military conflicts nuclear facilities could not only come under direct attack but could also be compromised unintentionally, again giving rise to nuclear accidents. Another important scenario to consider would be one in which the parties to the conflict attempt to take control of or disrupt a region's civil energy supply for tactical and strategic reasons. To accomplish this, the actors would have to gain direct control of a reactor or sabotage it. In the event of such a manoeuvre, a hazard to the safe operation of the facility could not be ruled out. Possible "collateral" damage, either directly or through error propagation, could reach an immense scale – whether or not this is intended by the combatants. Especially probable and relevant in this context is an interruption of the power plant's off-site electricity supply, which is discussed in the next section.

2.2. Sabotage and attacks

A further conceivable scenario is the attempt to carry out an attack using appropriate weapons and explosives or take control of a facility and deliberately sabotage it in order to cause a nuclear accident involving a massive release of radionuclides, or radiation. The blackmailing threat of such an action would be one step short of this scenario. Whether such an undertaking could succeed will essentially depend on the relative strength and technical adeptness of the attacker. Here it makes sense to distinguish between actors inside the facility, the penetration of the facility by intruders, and an attack from outside the power plant site.

Details of the anti-intrusion and anti-sabotage measures used to protect nuclear facilities are not published, for obvious reasons, and nor are the authors privy to such information. Generally it can be said that on the facility side, the protection consists of safety systems which have redundant elements and are spatially separated, control of access to sensitive parts of the facility and defence against unauthorised intrusion by means of doors, locking systems, fences, walls with video surveillance and the appropriate security staff. Likewise, all persons are controlled on entry to the site, and personnel who have access to the secure area regularly or by prior arrangement are vetted by the security authorities; for instance, in Germany this would mean the federal intelligence services.

Acts of sabotage by actors located within the facility could be directed by organisations (secret services, terrorist organisations). This would presuppose, as would direct military assaults, a premeditated motive on the part of one of the parties to the conflict as well as longer-term planning. Just as conceivable would be an inside perpetrator who perhaps sympathises with a party to the conflict, is sufficiently motivated to damage or destroy the facility and possibly even prepared to put his own life on the line. Such an actor would need to possess sufficient expertise in nuclear technology. His chances of success will essentially depend upon the capacities at his disposal. In (Öko-Institut 1983), for instance, it is assumed that in the event of a conceivable military escalation during the (then) Cold War, and given the involvement of governmental resources such as secret services, a sabotage operation's probability of success is extremely high, so that "in a first-order approximation, the probability of core meltdown is not substantially lower than the probability of a destroy command." (Öko-Institut 1983)

For intrusion into a facility by unauthorised persons, the expenditure of time and resources as well as the need for precise information about the facility are both relatively high. With regard to intrusion into the facility, the licensing procedures in the 1980s assumed, for purposes of analysis, a standardised individual perpetrator coming from outside the facility, who attempts to penetrate through to the reactor pressure vessel and the reactor coolant pumps and destroy them (Öko-Institut 1983). Sabotage is then excluded by specifying as part of the licensing procedure that outer and inner walls be sufficiently resilient that the attacker would have to use up the maximum quantity of explosive that he can carry before he has reached his target. A sabotage scenario in which the perpetrators break through into the secure area in chaotic war conditions, where they carry out a carefully planned sequence of hostile actions to destroy one safety mechanism after another, is dismissed by (Kovynev 2015) as belonging to the "realm of Hollywood cinema". The study (Öko-Institut 1983) draws the more cautious conclusion for German facilities that, in an overall risk identification, no significant risk contribution need be expected from sabotage by individual perpetrators or small groups of perpetrators penetrating a facility from the outside.

For an attack from outside the facility, appropriate weapons systems are necessary in order to cause sufficient damage. Moreover, sufficient knowledge about the general functioning of nuclear power plants, about the specific facility and about the layout of the individual parts of the facility are required (Öko-Institut 1983). For radioactivity to be released, however, it is not absolutely necessary to destroy the main cooling system of the reactor core. It can be sufficient to initiate transients and simultaneously to disable the safety systems necessary to control them, e.g. the entire electricity supply including the emergency core cooling system or the cooling water supply, and to prevent response measures. Equipped with the requisite armour-piercing munitions, a well-informed group of perpetrators numbering fewer than 10 individuals might be sufficient to destroy various systems practically simultaneously (Öko-Institut 1983). The study therefore comes to the conclusion that, assuming equal expenditure of effort, an attack from outside the facility would be easier to carry out than a hostile action from within the facility.

Beyond this, another vulnerability in many types of reactor is the radioactive inventory of the spent core elements in the nuclear power plant's cooling pond. A targeted attack with armour-piercing weapons might cause a loss of coolant so that heat could no longer be dissipated, resulting in the outbreak of a fuel element fire which can lead to massive releases of radioactivity.

The terrorist attacks carried out on the World Trade Centre and the Pentagon on 11 September 2001 by deliberately crashing civilian passenger jets also prompted a discussion on the safety of nuclear facilities, which ultimately led to an extended examination of "interference from outside" nuclear facilities including terrorist acts like the intentional downing of a plane. After the nuclear disaster in Fukushima, as part of the "lessons learned" the IAEA demanded the worldwide implementation of "stress tests" against sabotage from outside the facility. In Europe an evaluation of nuclear power plants was carried out, and in Germany this was extended to other nuclear facilities as well. As part of this process, measures were derived as necessary to improve safety with regard to sabotage from outside the facility. These were implemented or remain to be implemented within the scope of National Action Plans (ENSREG 2012; Hennenhöfer and Klonk 2014). Around the world many countries have carried out stress tests following the European model (Lankin 2014).

The safe operation of a nuclear power plant can also be compromised by damage to the connected infrastructure, particularly the power supply grid, whether or not attackers are necessarily aware of the impact on a nuclear power plant. An attack on the civil electricity supply such as the detonation of electricity pylons or transformer substations is a probable scenario in violent conflict situations, as recent incidents in Ukraine (see Section 4.3.1) have shown.

Nuclear power plants are designed to withstand a loss of off-site grid power. When the off-site power supply is lost, however, it is necessary to run down the reactor to the level sufficient to meet on-site power requirements to avert the actuation of emergency power (Öko-Institut 1983) and the necessity to draw electricity from the on-site emergency power system. In some cases a power plant can withstand such an incident undamaged, but the failure of safety systems is an ever-present possibility. This gives rise to a not-insignificant risk contribution, in the same order of magnitude as a loss of grid power to a nuclear power plant due to any other cause (Öko-Institut 1983). Accordingly, warnings have been issued repeatedly about the unintended consequences of attacks on the electricity grid.

2.3. Impacts of crises on the nuclear infrastructure

The use of nuclear energy demands an extensive institutional and material infrastructure, the effective functioning of which depends on stable intrastate conditions and interstate relations. Over and above direct interference affecting nuclear facilities, crisis situations can also entail substantial disruption to the institutional control and the safety culture governing the operation of facilities.

In most countries, alongside the operator and the manufacturer of the facility, a state infrastructure also exists to control compliance with statutory protection objectives for the population and the environment. Elements of this infrastructure are ministries and governmental regulatory authorities with corresponding specialist staff, which can ideally act independently of the operator in terms of personnel and expertise. In crisis regions, however, the activity of these institutions and their independence can be constrained in various ways. This may affect access to facilities, to information or to international expertise as well as the availability of specialist staff.

Questions also arise concerning the stresses to which the personnel of a power plant are exposed under crisis conditions. The causes may range from problems relating to their personal and family situations through to conflicts that split the operational staff into two camps. Human errors in the operation of reactors are likely to occur more often as a result.

Ultimately the operation of nuclear facilities relies on an extensive technical infrastructure which ranges from the supply of fuel, expendable and replacement parts to the technical and scientific monitoring of the nuclear infrastructure and the training of personnel. In a crisis situation this can become especially problematic if the manufacturer and the suppliers are located abroad, possibly in a country that has become a party to the conflict. This is the case in Ukraine, for example, which always was and remains very tightly integrated into the Russian nuclear infrastructure.

A strong bias towards nuclear energy generation within a country's energy sector can also have very negative impacts. As a result of such a bias, balancing decisions may have to be taken in crisis situations which require safety aspects of the facility to be weighed against the consequences of a large-scale power outage.

It is not solely in states affected by intra- or substate violent conflicts that negative impacts on the nuclear infrastructure may occur. States with inadequate or eroding intrastate structures are often also affected, e.g. unstable and decaying states, of which a small number are also pursuing plans to embark on the use of nuclear energy.

Apart from situations where the safety of the nuclear power plant itself is compromised, a final aspect to mention is the greater difficulty of exercising control over the radioactive inventory or even the absence of such control (Döschner 2016). A wartime erosion of intrastate structures or indeed a severe socio-economic crisis can lead to inadequate protection of the storage locations and inadequate monitoring and documentation of sources of radioactivity or none at all. This in turn heightens the level of risk that radioactive substances might be misappropriated and misused to build a “dirty bomb”. However, they might also accidentally fall into the hands of innocent parties, exposing them to hazards. There are countless examples of severe health impairments and fatalities due to radiation exposure caused by incorrect or careless practices in the handling of radioactive substances (e.g. see BMUB 2004). In Thailand in the year 2000, three people lost their lives and more than one thousand were exposed to excessive radiation due to the release of ionising radiation when a disused cobalt-60 medical irradiation device was found (IAEA 2002). In Germany in the years 2009 to 2014, a total of six finds of radiation sources with an activity greater than 1 GBq were reported, of which two can be classified as high-level radioactivity sources. No radiation was released in these cases (Motzkus et al. 2012).

2.4. Impacts on nuclear accident control

In the event of a nuclear accident, irrespective of its actual cause, the capability to control the nuclear accident itself and to minimise its consequences presupposes a functioning emergency response system and the capability to mobilise technical responses rapidly. In conflict or war situations, however, a state’s capabilities in these areas may have been weakened or lost. Any such weakening or the loss of the relevant capabilities would be directly associated with amplification of the consequences of an accident.

Last but not least, any release of radioactive substances can also have transboundary consequences and the control of these requires cooperation between states within the framework of emergency planning. Again, a war or an interstate conflict can compromise this kind of interstate cooperation.

2.5. Summary of nuclear risks in crisis regions

Nuclear facilities and the extensive nuclear infrastructure necessary for their operation including operators, suppliers, institutions and authorities, are reliant on stable interstate relations and intrastate conditions in order to ensure facility safety. If these preconditions are not in place or not adequate, additional risks arise which may lead to a nuclear accident.

As yet, it remains largely unclear how such risks to nuclear safety might be quantified. Various assumptions can of course be made regarding the necessary minimum protection of nuclear facilities, and the “disruptive actions” or other “interference by third parties” defined in that process become the underlying basis for the licensing of such a facility. Nuclear risks arising from conflicts or war cannot be fundamentally ruled out, however, and in a wider-ranging risk identification they tend to be externalised and either categorised as too improbable or not addressed at all. At the same time, it is neither possible to take long-term stable inter- or intrastate conditions for granted, nor ever truly improbable that violent conflicts or social crises will break out, even in regions which appear stable today.

Nuclear facilities are of course protected from “disruptive actions” and “interference by third parties” such as terrorist attacks and other acts of sabotage, but such protective measures are usually addressed solely to averting terrorist threats and presuppose the existence of a functioning governmental authority. Nevertheless, they cannot “exclude successful actions absolutely” (Öko-Institut 1983). Ultimately, even today’s types of facilities cannot be given complete protection against direct attacks. Thus, the protection of the facility can only be ensured from outside the facility, by means of appropriate military resources for instance.

In (Öko-Institut 1983) the different actors and causal pathways for that period are dealt with at length. In that publication it is argued that when conducting a full risk identification, the risk of a core meltdown caused by third-party interference would have to be lower than 10^{-4} to 10^{-5} per reactor-year to avoid making a significant contribution to the overall risk. By way of comparison: when it comes to disruption from outside the facility caused by natural phenomena (earthquakes, tsunamis, storms etc.), events with an exceedance probability of 10^{-4} per year should be incorporated into the design basis in Europe today. The attempt was also made in (Öko-Institut 1983) to assess certain probabilities and the authors argue that, for an adequate weighing of the risks, at least an attempt at quantification must be undertaken, although the determination of occurrence probabilities is difficult for systematic and statistical reasons and will always be beset with uncertainties.

The decisive factor for a determination of risks is the motivation of the attackers, from which greater or lesser numbers of individuals might draw motivation. The relevance of concrete scenarios depends not only on the objective to be attained but also on how often such an action is carried out. Thus, even attacks of seemingly minor significance, if they occur frequently, can have a high risk contribution if they occur in combination with other error sources. Moreover, the motives are subject to historical and societal change.

Whether the exclusion of nuclear risks arising from conflict situations is in fact adequate, taking account of the decades-long time span from the use of the nuclear power extending to the post-operational periods of shut-down facilities and the interim storage of highly radioactive wastes through to final storage, mirrored against the speed of social transformation, is highly questionable to say the least. It must also be said that today's nuclear power plants and those planned for the future are and will continue to be vulnerable to direct military attacks, and that the associated risks are not addressed sufficiently.

It is remarkable that comparatively little public discussion and reporting has taken place to date about the vulnerability of nuclear facilities in military conflicts. An assumption appears to be made that, along the same lines as for nuclear weapons, there is a kind of taboo whereby parties to the conflict refrain from any intentional attack to release such a facility's radioactive inventory.

A typical line of argument can be found, for instance, in (Kovynev 2015): admittedly the author recognises the necessity of considering military conflicts and demands that, for instance, new nuclear power plants be designed to withstand the crash of a military aircraft with a certain mass and velocity; but he then goes on to exclude all other hazards caused by military conflicts, based on the sweeping rationale that they are improbable ("negligible probability", "senselessness"). For intrastate conflicts, (Kovynev 2015) assumes that it would never make sense for any actor to release a radioactive inventory (not even for blackmailing purposes). While he acknowledges that no power plant could withstand active bombardment, he then asserts that this could only ever occur during interstate conflicts since it is not rational behaviour in intrastate conflicts.

However, such a view entirely negates the changing constellations of actors, which can only be touched upon briefly in this report. Thus, only twenty to thirty years ago the underlying assumption in relation to terrorist attacks was that "potentially sympathetic third parties" (Münkler 2016) from whom the terrorists hoped to gain support for their objectives (e.g. the population) would not be affected by a terrorist act. At that time, terrorist motives for attacking a nuclear power plant and intentionally releasing radioactivity could scarcely be imagined because the consequences could not rationally be brought into harmony with the motives, and consequently the act appeared senseless. The rationality gap between motive and action could only be bridged effectively with scenarios in which, for instance, secret agents in wartime were working to destabilise a country or even to deploy the power plant as a mine to combat advancing hostile troops. Or a mentally unstable individual perpetrator was assumed, who could inflict sufficient damage (an inside perpetrator, fighter jet pilot, etc.).

Today there are a range of actors for which the assumption that a rationality gap prevents such action does not necessarily apply in the same way; for instance, state or non-state actors who are actually counting on an excessively restrictive governmental reaction, when states adopt a reflex-like and media-driven response to terrorist acts by tightening up security and surveillance measures and thereby stray into danger of abolishing their own hard-won liberties. If there is no violence-limiting “presumed sympathetic third party” and all that remains is the governmental response, or if the massive fomentation of a conflict itself is the motive, then the past assumption of a rationality gap, on the basis of which there will never be an attack on a reactor to release radioactivity, is no longer justifiable in all instances.

Now as ever, the successful execution of such an attack remains technically difficult and can be viewed as a very complex operation which requires a group of highly determined and specially trained individuals.

In comparison to other civil infrastructure presenting potential targets for assault, nuclear power plants represent relatively hard targets; attack scenarios are therefore more demanding and more difficult in execution. On the one hand this diminishes the probability of nuclear power plants becoming a target; on the other hand, the public’s special alertness to radiological risks and the immense hazard potential from the release of radioactivity must be taken into account since these boost the incentive for such an attack. For groups with terrorist motives even a failed attempt can be sufficient to stir up fear and anxiety in the population, with correspondingly unpredictable consequences for the country’s civil society.

In the event of an attack on a nuclear facility in a crisis region, particularly when those carrying out the action on the ground cannot clearly be assigned to a specific party to the conflict, the attempted attack on a power plant will certainly be politicised immediately, or might also be entirely staged. The shooting down of an international civilian aircraft – Malaysia Airlines Flight 17 (MH17) – by one of the parties to the Eastern Ukraine conflict shows how wide the spectrum of different interpretations can be, from an unintended shootdown to a “false flag” action by one of the conflict parties so as to bring another party into international disrepute. The example also shows how difficult it can be on the ground to gain an overview of the situation, to obtain verified information, and to convey assistance, competent specialists and material to the scene.

Another scenario might be a state that finds itself forced to attack a civil nuclear reactor containing spent fuel elements because it assumes that the plutonium contained in the fuel elements is serving a military programme to build nuclear weapons.

As in other conflicts, there is a danger that criticism of nuclear safety, although technically and objectively justified, will be rapidly politicised. Technically justified criticism then becomes an economic obstacle, or foreign demands for greater safety become an attack on state sovereignty, or the operation of a power plant becomes an active threat or even a hostile act. Likewise during conflicts, considerations of energy autonomy and the prevention of economic damage can become a survival strategy that takes precedence over safety arguments. Various examples also demonstrate that the nuclear energy supply is part of some countries’ foreign policy strategy. Similarly as for oil as a fuel source, geostrategic interests are also in play in the nuclear sector.

In the event of an intentional act of sabotage or a terrorist attack on a nuclear power plant, it makes a difference how stable the state conditions are at the location of the power plant. In a country with a functioning governmental executive which can be mobilised rapidly and purposefully, or which issues warnings prior to the occurrence of hazards, the prospects of success for an attack on a nuclear power plant or use of unsecured radioactive sources to build a dirty bomb are reduced. In a crisis region in which there is no clear differentiation between terrorist groups, various armed militias and hybrid actors in the conflict, and in which the governmental executive is a much weakened presence, this is no longer true to the same extent. For this reason, in crisis regions like Ukraine, power plant sites are provided with additional security by military units (Section **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Overall, the most likely cause of a significantly increased risk of a nuclear accident in a crisis region will be the combination of several different factors. Even just the escalation of a political dispute can have repercussions for nuclear safety. Short-term decisions are made under time pressure and under the practical constraints of the political level. These can have a serious influence on nuclear safety, whether or not the decision-maker is or was aware of it – for example, conflict-driven personnel decisions can compromise the authorities' effectiveness. Added to this are factors ranging from political and social tensions, a degraded civil infrastructure, supply bottlenecks, insufficient control and quality assurance, and rising crime (theft, organised crime) right up to violent conflicts.

In a discussion about the safety of nuclear power plants in other countries, it should not be overlooked that criticism of nuclear safety can rapidly lead to demands that cannot be immediately fulfilled and are neither fair nor appropriate to the situation in the given country (effectiveness of measures). Demands for safety can also turn into accusations, which ultimately pay more service to the political agenda than to nuclear safety. For reasons of equity and state sovereignty, a state cannot be prohibited from using nuclear technologies, despite the associated risks and their consequences for neighbouring countries. It is all the more important, then, to cooperate with such states on questions of nuclear safety and to support them, but at the same time to insist that these countries, too, incorporate the risks arising from conflicts into their future energy-policy decisions. Over the long term and around the world there will continue to be some "safer" and some "less safe" nuclear power plants and nuclear facilities, which are vulnerable to a deliberate or an accidental attack or its incidental consequences.

3. Crisis regions with nuclear facilities

This chapter looks at several examples of crisis regions with operational nuclear facilities. Some are historical cases in which nuclear facilities were the target of terrorist attacks or intentional acts of war, but also included are examples from present-day crisis regions where the safety of existing nuclear facilities may be compromised by such action.

3.1. Crisis regions worldwide: the Conflict Barometer

The Heidelberg Institute for International Conflict Research (HIIK) monitors and categorises crises and wars in its Conflict Barometer (HIIK 2016). The following overview is based on the datasets compiled by the HIIK. Its definitions and categories are used here to identify examples of nuclear facilities affected by conflict. As discussed above, the term "crisis region", which is used in a general sense in this report, is not synonymous with the HIIK's definitions, which are grouped around the term "conflict".

The HIIK's Conflict Barometer is updated annually. The following comments are based on the latest version for 2015 (HIIK 2016) [2]. Where necessary, developments in specific conflicts are tracked by means of a comparison with earlier versions of the Barometer.

[2] The follow up of the report "Conflict Barometer No. 25" for the year 2016 was published after the completion of this study. For this reason, all the figures and references in this report refer to the previous report, issue No. 24 (HIIK

In its Methodology, the Barometer defines a political conflict as a perceived incompatibility of intentions between individuals or social groups. Conflict intensity is categorised as “low”, “medium” and “high” in the HIIK model, and a distinction is made between violent and non-violent conflict. This results in a four-point scale, which differentiates between:

- dispute or non-violent conflict, low intensity
- violent crisis, medium intensity
- limited war, high intensity
- war, very high intensity.

This scale is used globally for the comprehensive assessment of conflicts, as illustrated by Figure 3-1 for violent conflicts at the subnational level. In this context, “subnational” means a conflict within a region or regions, but not extending to the entire territory, of a sovereign state. The discussion focuses on those regions in which conflicts have occurred or are ongoing. Figure 3-1 therefore depicts the geographical conflict regions without reference to national borders; the nuclear power plant sites around the world are additionally marked.

According to the Conflict Barometer for 2015, the African continent, i.e. sub-Saharan Africa and the Maghreb countries, is burdened by interstate or subnational violent conflicts to a particularly high degree. Areas in the Middle East, Eastern Ukraine, Afghanistan and South-East Asia are also identified as conflict regions (see Figure 3-1).

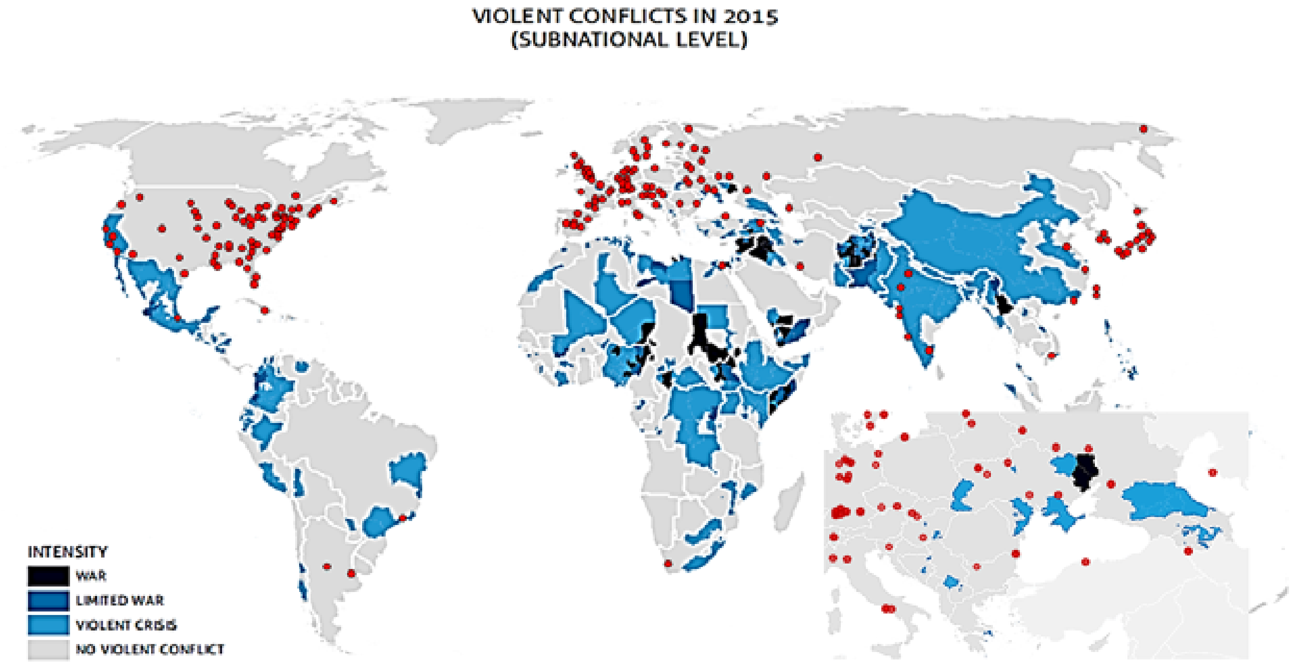
A number of regions falling within the “war” and “limited war” categories are located in African countries which have stated their intention or announced plans to construct nuclear power plants, including Kenya, Somalia, Sudan, Nigeria and Algeria.

In the Middle East, a number of conflict regions are identified in countries with nuclear facilities, notably Israel, Iran and Syria. Pakistan (which also has to contend with the destabilising effects of neighbouring Afghanistan) and India are the main countries affected by armed conflict in Asia. Within Europe, Ukraine – a country with a well-developed nuclear infrastructure – is classed as a conflict region. Russia is involved in this conflict, and the European Union also pursues strategic objectives here.

Even this brief geographical overview of crisis regions and nuclear sites shows that nuclear infrastructures are potentially affected by conflicts, some of them violent, all over the world. This raises the question of how nuclear energy for non-military purposes can ever be developed or utilised “peacefully” in a crisis region, and how effectively the consequences of a potential nuclear accident can be minimised in this type of conflict setting. This has become an increasingly urgent question for Europe, too, as a result of the war in Eastern Ukraine, for the effects of a serious nuclear accident here would spill over to other European countries.

2016). The comparison between the previous and follow-up issues of the Conflict Barometer showed that the conflicts‘ nature and extension in the considered regions in principle remain unchanged.

Figure 3-1: Conflicts at subnational level and nuclear power plants



Source: (HIIK 2016), nuclear power plant sites additionally marked

3.2. The Middle East and Asia

3.2.1. Iran, Iraq, Syria

As Figure 3-2 shows, the Iran, Iraq and Syria region is involved in a number of intense armed conflicts, ranging from violent crisis to war (see HIIK scale, Section 3.1 above). It is also at the epicentre of the strategic interests of countries such as the US, Turkey, Israel and Russia. As past events and incidents show, there is a high potential risk of a deliberate and targeted attack or unintended impacts upon Iran's nuclear facilities. Metsamor nuclear power plant in neighbouring Armenia may also be adversely affected.

- Iran/Iraq: the wars in the Persian Gulf and their consequences

In collaboration with France, Iraq began the construction of a nuclear power plant, consisting of one main reactor (Osirak) and a research reactor, in 1976. During the Iran-Iraq War, Iranian combat aircraft carried out an air strike on the incomplete Osirak reactor but failed to cause serious damage, not least due to the absence of nuclear fuel. A year later, the reactor was destroyed in a targeted Israeli air strike. Air strikes carried out by the US during the Second Gulf War subsequently destroyed the entire site with the aim of preventing Iraq from proceeding with its suspected nuclear weapons programme. Again, no fuel was present at the site at the time of the attacks.

At present, a number of militant organisations, some with support from abroad, and various militias are operating on the territory of Iraq, which is currently in the throes of a full-scale civil war.

Iran has operated a research reactor since 1967 and commissioned its first conventional nuclear power plant at Buschehr on the Persian Gulf in 2011. In addition, it has two uranium enrichment facilities and one fuel manufacturing plant. The research reactor and fuel manufacturing plant are located near Tehran (see Figure 3-2). The Tehran Nuclear Research Centre opened in the 1990s. Iran also has various uranium mining operations. The international community has frequently criticised Iran for the ambiguous nature of its nuclear programme, which may or may not have military as well as civilian applications, and has imposed sanctions on various occasions. International negotiations with the five permanent members of the UN Security Council (China, France, Russia, the UK and the US) plus Germany led to an agreement on transparency and monitoring of the Iranian nuclear programme in 2015 (WNA 2016). However, the outcomes of these negotiations came in for sharp criticism from Israel, and political tensions between Iran and Israel subsequently intensified as events unfolded (Holger Stark 2015; FOKUS 2015; M-Magazin 2015; Reuters 2016). Israel has been threatening for years to carry out a preventive military strike against Iran's nuclear facilities in order to halt what Israel suspects to be a build-up of nuclear weapons by Iran.

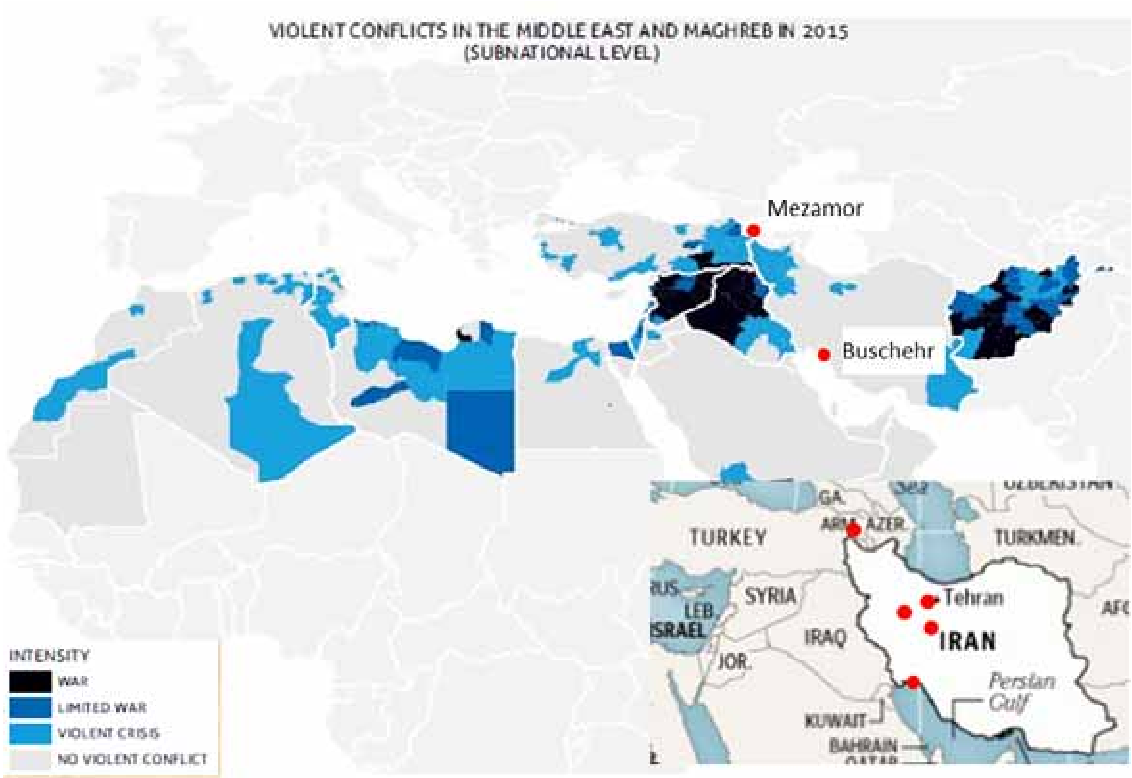
- Syria

Syria has been in the grip of a full-scale civil war, in which there is considerable direct and indirect foreign involvement, since 2011. In 1991, Syria – with support from China and the IAEA – began to build the (Mini)Research Reactor-1 (MNSR (SYR/4/009)) at the Der Al-Hadjar Nuclear Research Center near Damascus. The reactor has been operating under the IAEA safety standards programme since 1996 (IAEA 2015). However, this particular reactor has a very small radioactive inventory.

According to Western media reports, Syria – with support from North Korea – began to construct a power reactor (Deir al-Zour) prior to 2007 (Kovynev 2015). During the conflict between Israel and Syria, Israeli military aircraft destroyed the suspected reactor complex in a surprise airstrike on 5 September 2007. The Bashar al-Assad government stated that it had no plans to build a power reactor and denied the existence of the construction project. However, in 2011, the IAEA confirmed that an air strike on an (unfuelled) reactor in Syria had indeed occurred (Kovynev 2015).

This incident is yet another example of a strategic attack on a nuclear facility being motivated by suspicions about a clandestine nuclear weapons programme. Syria has ratified the Nuclear Non-Proliferation Treaty and, at least officially, currently has no nuclear weapons development programme or nuclear arsenal of its own. According to the IAEA, there is no reliable evidence of the development in Syria of an industrial infrastructure with nuclear weapons capability (IAEA 2015).

Figure 3-2: Conflicts in the Middle East, based on the HIIK classification, and nuclear facilities officially in existence and currently operating



Source: Depiction of conflict regions (HIIK 2016) and map of Iran (PUBLIC DOMAIN) with nuclear power plant sites additionally marked

3.2.2. Armenia-Azerbaijan

Armenia's sole nuclear power plant is located at Metsamor, around 10 km from the Turkish border (Figure 3-3). The plant contains two VVER-440 Model V270 reactors, each with a capacity of 440 MWe and almost 40 years old, and is still generating electricity. In the European Union, reactors of this type have been shut down due to their poor resilience to external shocks (examples are Greifswald and Bohunice). The 1988 Spitak earthquake initially resulted in the shutdown of the two reactors in 1989.

This coincided with a renewed flare-up of the conflict between Armenia and Azerbaijan over the enclave of Nagorno-Karabakh in 1988 (Figure 3-4), with fighting between the two countries' armed forces lasting from 1992 to 1994. Russia and Turkey were also involved in the conflict, siding with Armenia and Azerbaijan, respectively. A ceasefire treaty was signed in 1994. Nonetheless, further armed clashes occurred in 2008, 2014 and 2016.

Metsamor was scheduled for permanent shutdown after the earthquake due to concerns about seismic vulnerability. However, with Armenia facing a severe energy shortage as a consequence of the conflict over Nagorno-Karabakh and an economic and transport blockade imposed by both Azerbaijan and Turkey, Reactor 2 was recommissioned and has been generating electricity again since 1996. Reactor 1 remained permanently closed. According to official information from the IAEA, various measures were taken to improve safety, with around US$ 50 million invested in the plant. Some of the most serious defects were rectified with external assistance, mainly from Russia, including improvements to seismic resistance and the installation of new fire doors. Due to the design of the now obsolete VVER reactors, the facility has no containment structure. Although the Spitak quake in 1988 was the most powerful to hit Armenia in years, the Metsamor plant is located in an area of high seismic hazard and even stronger earthquakes are therefore to be expected in future (Lavelle and Garthwaite 2011). Safety at the Metsamor reactor still gives cause for concern and comes in for frequent criticism, particularly from Turkey.

As part of a deal on the repayment of a Russian loan, Russia and Armenia reached an assets-for-debt agreement which involved the transfer of operational control of Metsamor to a Russian company. This controversial arrangement was widely criticised, for in a country like Armenia, where corruption is rife[3] and state control is weak, there are major concerns about the potential for the operation of the reactor to be instrumentalised for foreign policy purposes or to put pressure on the government or its agencies. Depending on the circumstances, this may have positive or negative implications for the nuclear risks. Russia, for example, has a considerable interest in Armenia's normalising its relations with Turkey as this would create new transport routes and pipeline connections for Russian natural gas. However, instability throughout the region has recently increased as a result of a renewed escalation in the conflict between Turkey and Armenia and the worsening of relations between Turkey and the EU. It is a matter of speculation whether this is more or less likely to result in the shutdown of Armenia's obsolete nuclear power plant and the construction of a new reactor, which has been under discussion for some years. Works to upgrade facility safety are scheduled for 2017.

[3] Armenia ranks 133rd out of 176 countries surveyed in the latest Corruption Perceptions Index (2016) http://www.transparency.org/news/feature/corruption_perceptions_index_2016

Figure 3-3: The Metsamor nuclear power plant in Armenia and the 1988 earthquake epicentre

Source: (Lavelle and Garthwaite 2011)

Figure 3-4: Armenia, Azerbaijan and the Nagorno-Karabakh conflict region (NKR)

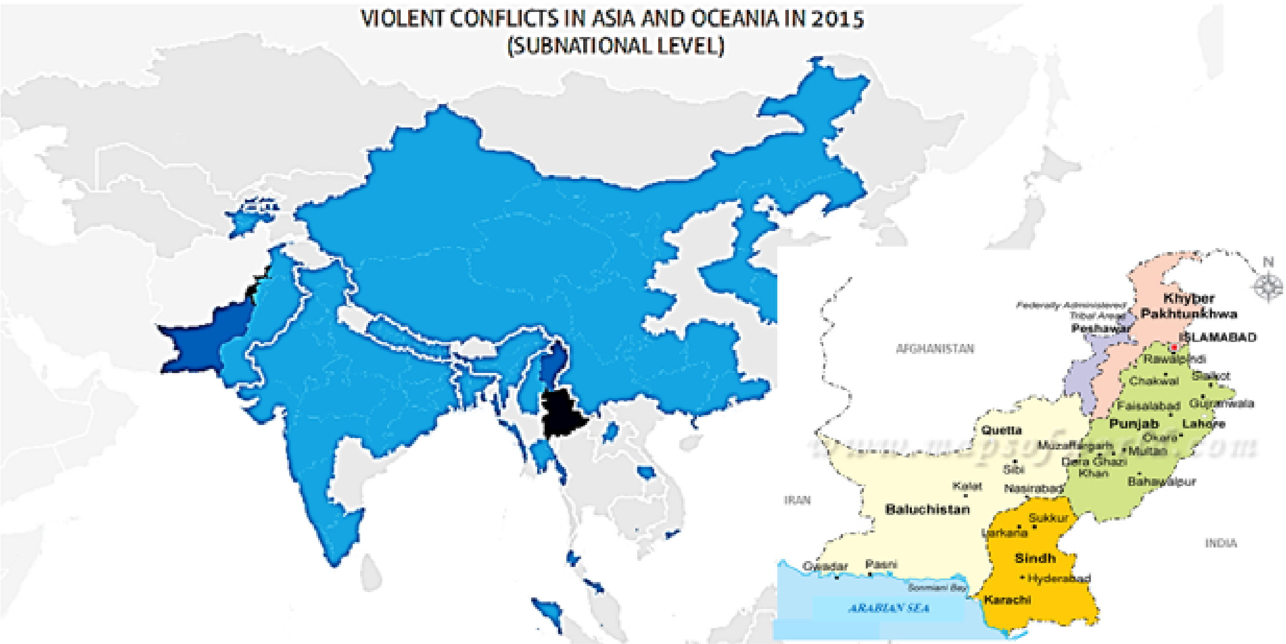
Source: Wikipedia

3.2.3. Pakistan, India and Afghanistan

The conflict between India and Pakistan over the state of Kashmir and Jammu in northern India dates back to the partition of India and the formation of Pakistan in 1947. In all, four Indo-Pakistan wars were fought between 1947 and 1999, in addition to lesser crises and various armed clashes which threatened to escalate into war between these two countries, both of which have nuclear weapons. A ceasefire agreed in 2003 was broken by localised clashes in 2014. In 2015, fresh negotiations on future status issues began. However, the conflict between Pakistan and India is not only about the status of the disputed territory but also about water and other resources (HIIK 2016; IRIB 2015).

In Pakistan, the situation in the southern province of Sindh, where there is a violent conflict involving various ethnic groups, is also potentially explosive. In addition, there is a much more serious conflict between Islamist militant groups, on the one hand, and the Government, backed by the US, on the other (HIIK 2016), which led to war, mainly in the northern province of Khyber Pakhtunkhwa, in 2014. As a result of terrorist activities, the conflict has now spilled over to the rest of Pakistan. According to the Conflict Barometer (HIIK 2016), all parts of Pakistan are now affected by violent conflict (see Figure 3-5).

Figure 3-5: Conflict in the region of Pakistan, India and Afghanistan and nuclear power plants in Pakistan



Source: (HIIK 2016); map of Pakistan: Copyright © www.mapsofworld.com with nuclear power plant sites additionally marked

Pakistan operates two nuclear power plants at Karachi and Chasma (on-stream since 1972 and 2000, respectively; see Figure 3-5). Chasma is the larger, with two reactors, and is located in the province of Punjab – which borders not only Kashmir and Jammu but also Khyber – 250-300 km from the conflict regions (see Figure 3-5). The possibility that the operation of the plant may be adversely affected, with implications for nuclear safety, cannot be ruled out.

Across the border from the unstable regions of Northern Pakistan are highly unstable regions of Afghanistan (HIIK 2016). The mainly intrastate conflicts in Afghanistan involve various warring factions and began in 1994 (Taliban, Haqqani network, Hezb-i-Islami) and 2007 (Kuchi nomads vs. Hazara). Some Afghan armed groups, militias and Islamist militant organisations use Pakistani territory as a safe haven.

3.3. Developments in Europe

3.3.1. Civil war in Yugoslavia

After 1945, Europe was thought to be peaceful until an intrastate conflict between Yugoslavia's constituent republics escalated into civil war, lasting several years, in the early 1990s. The individual regions were affected to varying degrees. Krško nuclear power plant on what is now Slovenian sovereign territory was put at risk on several occasions. In June 1991, three Yugoslav Air Force fighter bombers flew over the plant. This clearly constituted a threat, with the destruction of the reactor and the potential release of the radioactive inventory being used as a deterrent. The reactor was temporarily shut down.

Three months later, the front line of the war in Croatia shifted closer to the border with Slovenia. Fighting broke out in the area around Zagreb, just 40 km from the nuclear plant (Stritar and Mavko 1992) (Hirsch 1997; Hirsch et al. 2005).

Although now located on Slovenian territory, the power plant is jointly owned by Slovenia and Croatia. The operation of the plant and the use of the energy it produces are regulated by intergovernmental agreements. However, the responsibility for interim and final storage of radioactive wastes is still a matter for negotiation. It is partly due to this situation that there is still no firm plan for the final storage of high-level radioactive waste (HLW).

3.3.2. Disintegration of the Eastern bloc: dissolution of Czechoslovakia

The fall of the Iron Curtain in 1989 also triggered various political shifts in the former Eastern bloc countries, although fortunately, they did not escalate into violent conflict. In the case of the former Czechoslovakia, for example, the issues affecting relations between the two nations were resolved diplomatically through "divorce" and the founding of two independent countries in 1993. With the ensuing decline and fragmentation of the nuclear industry supply networks in the former Soviet Union and other Warsaw Pact countries, however, some aspects of nuclear facility safety became more complicated. Depending on their respective locations, responsibility for operations and safety at Czechoslovakia's three nuclear power plants – Temelín, Dukovany and Bohunice – now had to be built into the institutional and administrative frameworks of the newly established Czech or Slovak Republic, as appropriate.

The disintegration of the Eastern bloc in 1989 set in train a transition from contractual dependency on the former Soviet Union for the supply and reprocessing of nuclear fuels and, in some cases, the return of spent fuel for final storage. The agreement on the return of spent nuclear fuels to the Soviet Union for final storage lapsed in 1989, whereupon the responsibility for safe disposal of high-level radioactive waste passed to the former Eastern bloc countries themselves. For the young Slovak Republic, however, the joint interim and final storage facilities that were planned or operating in Czechoslovakia were now located in another country. In 2001, Slovakia opened its own national near-surface storage facility for low- and medium-level wastes in Mochovce, close to the site of the nuclear power plant. The situation became rather more complex for the Czech

Republic, too: it now had to take back its spent fuel elements from interim storage at Slovak nuclear plants and establish suitable facilities of its own.

Czechoslovakia's amicable divorce posed no immediate threat to nuclear safety. Nonetheless, this example highlights the considerable interlinkage between governmental and industrial structures in the nuclear energy context and shows how the partition of a country, even under peaceful conditions, may impact on complex nuclear infrastructure, requiring comprehensive restructuring and alternative investment.

3.4. Embarking countries

Despite all the obstacles, many countries are showing interest, some more seriously than others, in building a domestic nuclear industry. This section therefore explores the ever-topical issue of embarking countries[4], with a particular focus on political stability – a fundamental prerequisite for the development of a nuclear infrastructure. Analysing this topic with the level of detail that it deserves would be beyond the scope of this paper. However, it is important to shed light on certain aspects of these statements of intent, especially those issued by countries whose governance architecture cannot be regarded as sufficiently stable but whose nuclear ambitions are nevertheless being encouraged by others with a well-established nuclear industry.

There are many examples to show that highly publicised announcements – usually by local economic and/or political elites – of plans to start using nuclear energy or build nuclear power plants in economically weak and politically unstable countries often come to naught or rarely progress beyond the initial statement of intent. Leaving aside the poor success prospects of these initiatives, these are circumstances in which the issue of nuclear safety should be given especially rigorous consideration. Even within a framework of peace and stable governance, establishing a nuclear infrastructure is a challenging task which requires a range of conditions to be in place (IAEA 2011). An embarking country must first establish the relevant government bodies, including regulatory, supervisory and other authorities, and make adequate contingency plans for emergencies. Training must be provided to build a pool of local expertise, which can take years or even decades in an embarking country. The issues of site selection and nuclear fuel supply and disposal must also be addressed, with particular emphasis on safety and security.

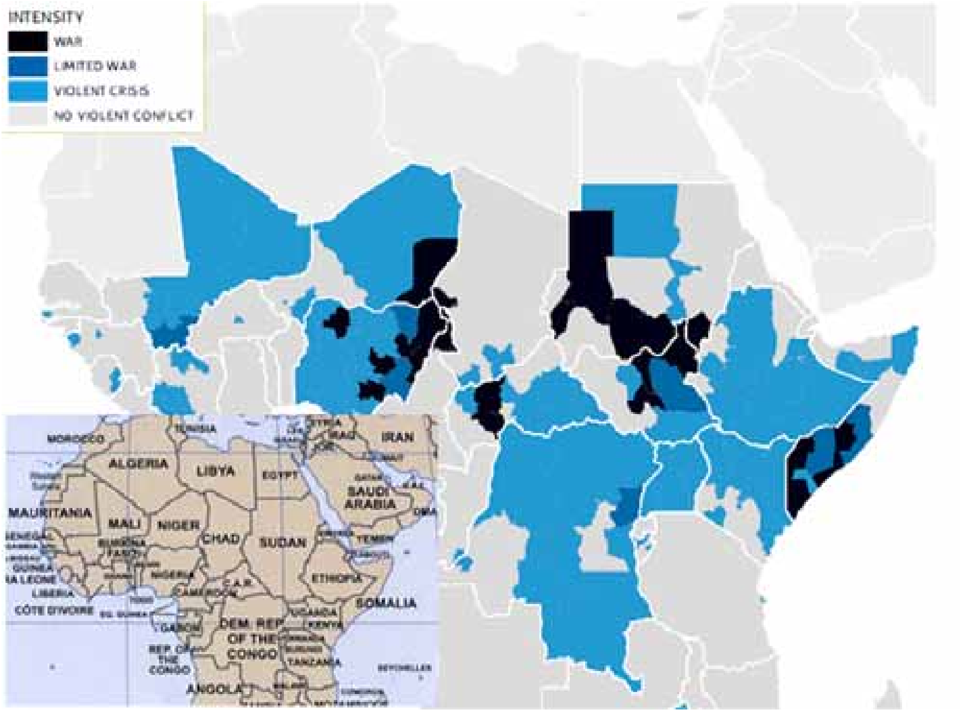
These are not really the conditions that are found in every embarking country.

A glance at Central Africa reveals the difficulties. Sub-Saharan Africa (SSA) includes three of the largest uranium resource-holders in the world – Namibia, Niger and South Africa, closely followed by Malawi. At present, there is only one nuclear power plant on the entire African continent, located at Koeberg in South Africa, with two reactors. South Africa has long nurtured – albeit unsuccessful – ambitions to expand its nuclear energy programme despite the frequent upheavals in the country caused by intra- and interstate conflicts. Nigeria, for its part, has been planning for some time to include nuclear power in its energy mix to meet increasing demand for electricity and support economic development. According to the IAEA, Nigeria is making notable progress in setting up the nuclear infrastructure that would be needed (Shepherd 2015). Namibia currently imports around half of its electricity from South Africa and has also expressed interest in the possibility of launching a domestic nuclear power programme to meet its energy needs. Kenya is seeking assistance with a view to developing a civilian nuclear power programme. The Government of Angola has expressed similar interest, while Sudan, Algeria and Ghana are looking for technical and financial support. (Shepherd 2015) examines these developments purely in terms of the nuclear industry's economic interests and long-term investment opportunities but largely disregards

[4] See, for example, https://gnssn.iaea.org/regnet/embarking/Pages/default.aspx

the political dimension. An industry overview of countries actively considering embarking upon nuclear power programmes is provided in (WNA 2017).

Figure 3-6: Conflict regions in Central Africa



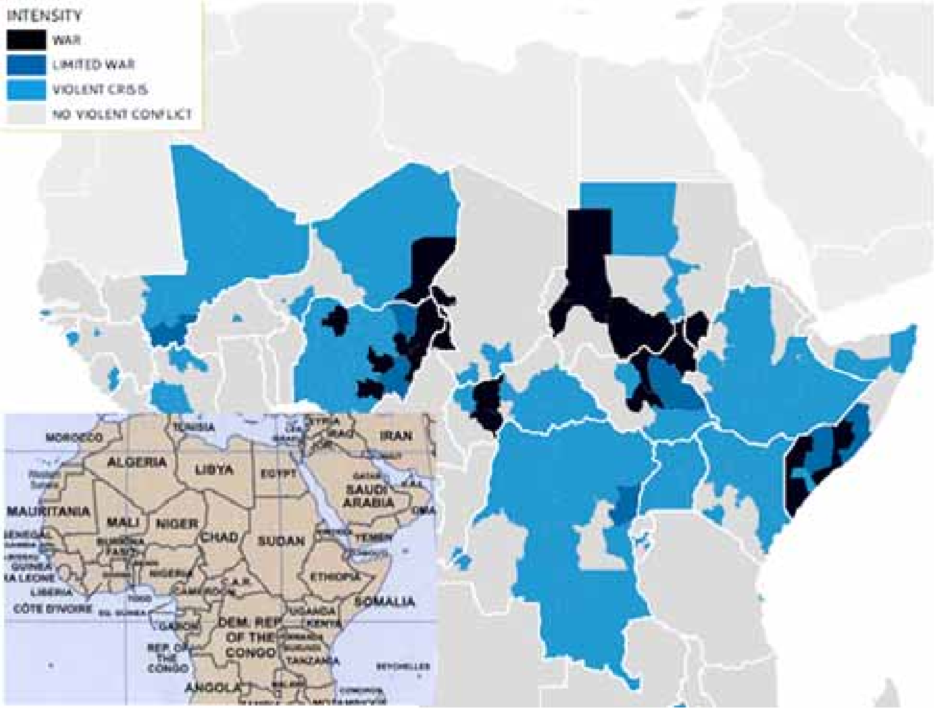
Source: (HIIK 2016); map of Africa: PUBLIC DOMAIN

(HIIK 2016) identifies a number of Central African countries and regions with violent conflicts, limited wars or even wars, including Niger/Nigeria, Sudan and Kenya (Figure 3-6). Corruption is endemic in these countries[5]. Nevertheless, their present governments have signalled an interest in launching nuclear programmes. Despite situations of instability in practically every country in North Africa, announcements of plans for new nuclear programmes are frequently reported from this region too, even from countries affected by civil war (e.g. Libya) or government instability (e.g. Algeria, Egypt). It is a similar situation in the Middle East, where a number of countries – including Yemen and Syria, which are in the grip of civil war – have announced plans to explore civilian nuclear energy (Fitzpatrick 2008).

Notwithstanding the various governments' statements of intent, establishing new nuclear energy programmes in regions of high political instability clearly makes little sense. The case studies presented earlier in this chapter show how quickly a supposedly stable country can be drawn into a conflict situation, and the risk is even greater in countries affected by political instability. That being the case, it is all the more astonishing that the nuclear industry is still thinking about "business opportunities" here (Shepherd 2015; WNA 2016, 2017).

[5] Sudan currently ranks 170th out of 176 countries listed in the Corruption Perceptions Index 2016, with Kenya and Nigeria appearing in 146th and 136th place, respectively. http://www.transparency.org/news/feature/corruption_perceptions_index_2016

Figure 3-7: Conflict regions in Central Africa



Source: (HIIK 2016); map of Africa: PUBLIC DOMAIN

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3.5. Summary: conflict regions and nuclear safety

As the above examples show, nuclear safety may be adversely affected by the escalation of a conflict or by combat operations. They also show how quickly regions long assumed to be stable can descend into fragility.

[6] Sudan currently ranks 170th out of 176 countries listed in the Corruption Perceptions Index 2016, with Kenya and Nigeria appearing in 146th and 136th place, respectively. http://www.transparency.org/news/feature/corruption_perceptions_index_2016

As the decade or so of civil war in the former Yugoslavia demonstrates, even a European country widely assumed to be stable is not immune to the outbreak of armed conflict. The military threat of an air strike on the Krško nuclear power plant and the ground war in its vicinity show how a nuclear facility can easily end up exposed to the hazards of an armed conflict.

The nuclear infrastructure or a nuclear power plant itself may become a strategic target in combat operations; one example is the bombing of an Iraqi reactor by Iran during the Iran-Iraq War. It may also become a pawn in militarised foreign policy, as Israel's threats against Iran's nuclear facilities show. Armenia's nuclear power plant at Metsamor, whose shutdown is long overdue, attests to the complex links between conflict and the implications for facility safety. Years of fighting, severe energy shortages caused by the intervention of hostile neighbours, and political calculation all have an indirect bearing on the risks posed by and to this elderly reactor, which is located, what is more, in an area of high seismic hazard. The geostrategic interests of neighbouring Russia and Turkey, also involved in the conflict, Armenia's dependence on nuclear energy, a corrupt political system and the possibility of hostilities flaring up again at any time are a potent mix in the context of nuclear safety.

Even if they are not specifically targeted, there is a greater probability of adverse impacts if nuclear facilities are located close to regions of conflict and instability, especially if these impacts are unintended and therefore not factored into conflict parties' calculations. This applies, for example, to the region of instability along the border between India and Pakistan and to various conflicts between Afghan armed groups, militias and Islamist militant organisations in neighbouring Afghanistan, which affect Pakistan as well due to its use as a safe haven.

As the cases discussed here show, damage to a nuclear facility during armed conflict cannot be dismissed as an "unlikely event".

Even peaceful solutions to political conflicts – such as the dissolution of the former Czechoslovakia and the founding of two independent countries, the Czech and Slovak Republics – can have implications for nuclear safety, demonstrating the nuclear infrastructure's complex dependence on state institutions. It also highlights the potential complications which can arise during restructuring after the founding of a new independent state. In this instance, structures which had previously been utilised by both these new countries now had to be dismantled and new independent systems established. In addition, complications arose in connection with the lapsing of the agreement on the return of spent nuclear fuels to the Soviet Union for final storage, whereupon new national solutions for safe disposal of radioactive waste needed to be devised and implemented for each of the two newly-founded countries.

4. Dissolution of the Soviet Union, escalation of the conflict in Ukraine

The dissolution of the Soviet Union in the 1990s also resulted in fragmentation of the centrally organised operation of its nuclear infrastructure, which passed to the successor states in which the various facilities were located. The loss of centralised control over the safety of these facilities was partially offset by the founding of the Commonwealth of Independent States (CIS), whose members included Russia, Ukraine[7], Belarus and Armenia – all countries with nuclear infrastructure. However, several of the CIS states later became flashpoints in political and, in some cases, armed conflicts.

The Baltic states – Latvia, Lithuania and Estonia – took a different route, however, and joined the European Union. As a consequence, nuclear facility safety in these countries is governed by

[7] On 19 March 2014, Ukraine announced its intention to leave the CIS.

agreements with the EU, which has also provided funding for the upgrading or dismantling of decommissioned power plants (Öko-Institut 2013).

The economic reforms implemented in Ukraine in the 1990s led to the emergence of a form of “clan capitalism”. The subsequent transition to a market economy initially improved Ukraine’s legal and economic frameworks. However, the 2008 global financial crisis hit the Ukrainian economy particularly hard. In 2014, the political conflicts over the future direction of the country’s foreign relations escalated (LPB 2017). A civil war erupted between the Ukrainian Government and proponents of autonomy or even separatism in Eastern Ukraine, with its majority Russian population. Issues at the heart of the conflict – besides the controversy over the future eastern or western orientation of Ukraine’s political system – include the secession of some of its territories and control over local resources, especially in the Donbas, a mainly Russian-speaking region of heavy industry and mining consisting of the Donetsk, Kharkiv and Luhansk oblasts (HIIK 2016). As well as the Ukrainian armed forces and separatist militia, various mercenary units and nationalist volunteer battalions are involved in the fighting (HIIK 2016).

There is another crisis region in Ukraine, namely the territory of Crimea. The long-lasting conflict between the Crimean Tatars, on the one hand, and the Crimean regional government and Russia, on the other, has been escalating since 1988. With the Black Sea port of Sevastopol, Crimea has immense military and strategic significance for the Russian Federation, which uses the port on an extraterritorial basis. As a result of the escalation in 2014 and Russia’s annexation of Crimea, which is not recognised by the world community, the situation has worsened in the international context as well (HIIK 2016).

According to estimated figures from the United Nations (UN 2015), at least 9000 people were killed in the conflict in Ukraine from April 2014 to November 2015. Infrastructure has been severely damaged in many areas, and in addition, approximately one million people have fled to neighbouring countries, most of them to Russia. Humanitarian access has been restricted in certain areas due to heavy fighting (HIIK 2016). Despite diplomatic efforts by the international community and negotiations involving the European Union, Russia and the OSCE (Minsk I and Minsk II agreements), there has been no permanent easing of tensions: the civil war continues, with the frequent eruption of renewed fighting and the situation in some areas still out of control (HIIK 2016).

4.1. Nuclear facilities in Ukraine

Despite the major accident at the Chernobyl nuclear power plant and the events of recent years, Ukraine is still heavily dependent on nuclear energy. It operates four nuclear power plants with 15 reactors and total installed capacity of around 13,000 MW (see Figure 4-1). The plants produce roughly half of Ukraine’s electricity. The Ukrainian Government is extending the lifetimes of its reactors: originally designed for 30-year operating lives, they will now run for 40 or even 50 years (see Table 4-1).

As early as 2014, German nuclear experts were alerted to the events in Ukraine and warned about the risks that the conflict posed to nuclear safety, emphasising that a stable situation was essential for the safe operation of the country’s 15 reactors and the decommissioning of Chernobyl. Conditions of conflict create the potential for unpredictable attacks, including terrorism, and the rapid disintegration of hierarchies and command structures. But the risk is not limited to the nuclear power plants; conflict makes it extremely difficult to guarantee the safety and stability of the power grid as well (Deutsche Welle 2014).

Safe interim and final storage of radioactive waste presents a particular challenge. An arrangement with Russia to reprocess spent nuclear fuel expires in 2018. Ukraine still lacks a national strategy for the management of high-level radioactive waste[8]. In the survey of experts (see Chapter 5), some respondents mentioned the existence of a large number of storage sites and their radioactive inventories as a source of risk in this context (see Section 2.3 on storage locations for sources of radioactivity).

4.1.1. Ukrainian and Russian nuclear power plant sites near the crisis region: Zaporizhzhya, South Ukraine and Novovoronezh

Zaporizhzhya is the largest nuclear power plant in Europe. This multi-unit plant, operated by the national nuclear energy generating company Energoatom, has six VVER-320 reactors (1-6), each generating 950 MWe. There is also a centralised dry storage facility for spent fuel (CSFSF) at the site. In 2014, almost 1600 tonnes of nuclear fuel were stored on-site.

All six reactors are located on the southern banks of the Kakhovka Reservoir, from which the power plant draws its cooling water and which is also used to supply the peninsula of Crimea. Five other reservoirs are located upstream of the site. Due to the power plant’s reliance on the filled reservoirs, any breaches of their dams could have an adverse effect on the reactor’s cooling water supply.

The site is located around 150 km (linear distance) to the west of the conflict zone in Donetsk oblast (Figure 4-1) and approximately the same distance to the north of the Black Sea peninsula of Crimea, annexed by Russia.

The **South Ukraine nuclear power plant** comprises two twin reactors and one single reactor of various types (VVER-1000/V-302, VVER-1000/V-338 and VVER-1000/V-320). The two twin units are technical forerunners of the single VVER-1000/V-320 reactor and are said to be highly vulnerable to rupture of the main steam lines. As twin units, these four older reactors have many shared systems, which means that their system redundancy is on the low side.

Beyond Ukraine’s eastern border with Russia is the **Novovoronezh nuclear power plant** (Figure 4-1). Of all of the Russian nuclear facilities, this is closest to the crisis region: it is located approximately 350 km linear distance from Luhansk in Ukraine. There are two power plants at the site: Novovoronezh nuclear power plant is Russia’s oldest commercial NPP and has been in operation since 1964. Three of its units (VVER-210, VVER-365 and VVER-440/179) have been shut down; two (VVER-440/179 and VVER-1000/187) are still in operation. Novovoronezh II currently consists of one reactor under construction and another which came into commercial operation in February 2017. These are Generation 3 reactors (VVER-1200/392M, based on the AES-2006 design). To what extent the site, located close to the border, could potentially be affected by an escalation of the civil war in Eastern Ukraine is uncertain.

4.1.2. The Chernobyl clean-up

Chernobyl, which has four decommissioned RBMK reactors, is located in Northern Ukraine near the city of Pripyat (Figure 4-1). On 26 April 1986, Reactor No. 4 exploded in what was to become the world’s first nuclear disaster to be rated 7, the highest severity score (major accident) on the International Nuclear and Radiological Event Scale (INES). Due to the continued presence of fuel in the reactor, it was initially enclosed in a concrete and lead sarcophagus to prevent further

[8] A detailed discussion of the storage of radioactive waste in Ukraine is beyond the scope of this report. It should be noted, however, that nuclear waste repositories, particularly wet-type facilities, are vulnerable to attack, potentially resulting in the release of radioactivity.

escape of radioactivity. However, the sarcophagus soon showed signs of damage and needed to be repaired. In 1997, the European Union and Ukraine reached agreement on the provision of additional funding for remedial activities at the site. Thirty years after the disaster, there is still a considerable radioactive contamination legacy (Röhrlich 2015). It was decided that the sarcophagus – now in a poor state of repair – should be replaced with a new shelter, known as the New Safe Confinement, but its construction was delayed, partly due to the Ukraine conflict (see Section **5.3**). The final stage in the process – sliding the structure into position over the ruins of Unit 4 – did not take place until late 2016.

In addition, large quantities of liquid radioactive waste from the site's three other decommissioned reactors must be disposed of and the 21,000 used fuel assemblies from Units 1-3 placed in interim storage. Since October 2013, these fuel elements have been kept in an old wet-type interim storage facility. A new interim dry storage facility should be available from 2018.

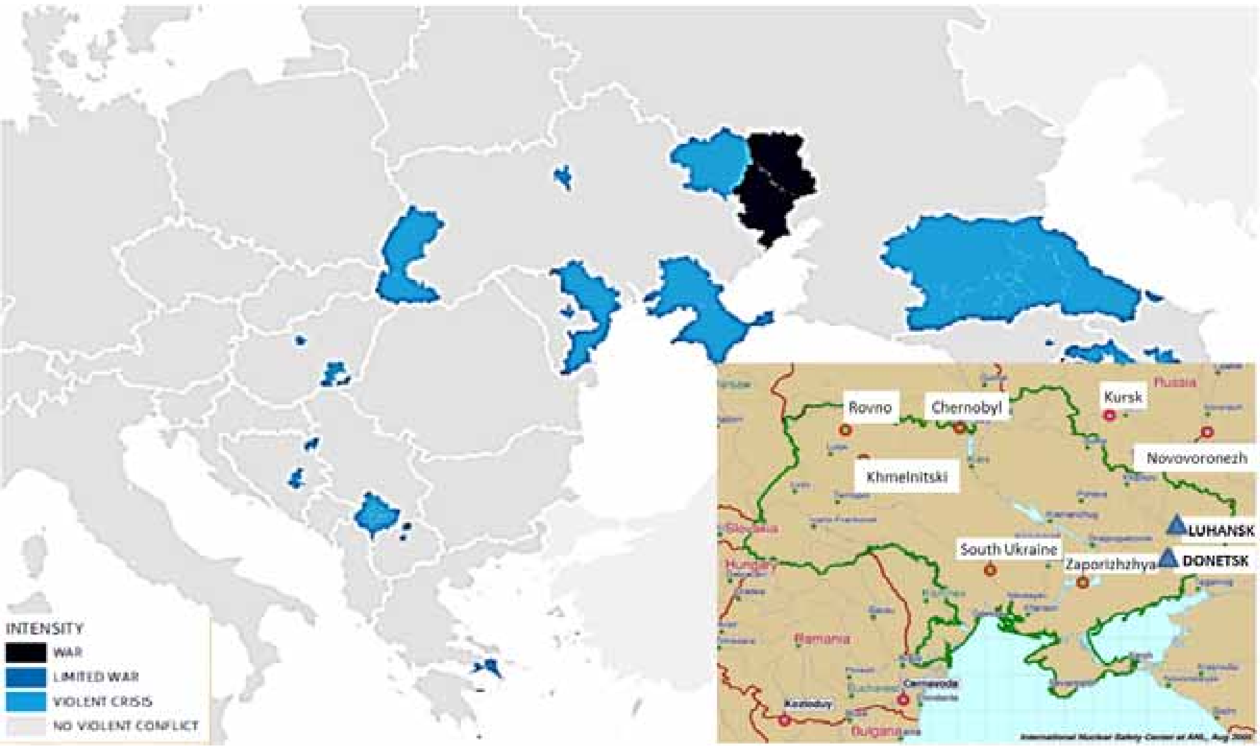
Ukraine does not currently have the resources to undertake the safe decommissioning of the Chernobyl site without assistance, far less to initiate the dismantling of the destroyed reactor in the wreckage of Unit 4. After years of mismanagement and faced with a crippling budget deficit, to say nothing of the conflict in Eastern Ukraine, the Ukrainian authorities' capacities to manage the clean-up at the Chernobyl site are extremely limited. According to Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, a German organisation with expertise in the field of nuclear safety and radioactive waste management which is involved in projects in Chernobyl, the scope to continue the clean-up is severely constrained by the conflict (Röhrlich 2015).

Table 4-1: Ukrainian power reactors: original lifetimes and proposed life extensions

Reactor	Type V=PWR	MWe net	Start of commercial operation	Scheduled close, likely close after extension
Northwest:				
Khmelnitski 1	V-320	950	August 1988	2018, 2032
Khmelnitski 2	V-320	950	August 2005	2035, 2050
Rivne/Rovno 1	V-213	381	September 1981	2030
Rivne/Rovno 2	V-213	376	July 1982	2031
Rivne/Rovno 3	V-320	950	May 1987	2017, 2032
Rivne/Rovno 4	V-320	950	late 2005	2035, 2050
South:				
South Ukraine 1	V-302	950	October 1983	2023, 2033
South Ukraine 2	V-338	950	April 1985	2025
South Ukraine 3	V-320	950	December 1989	2019, 2034
Zaporizhzhya 1	V-320	950	December 1985	2030
Zaporizhzhya 2	V-320	950	February 1986	2016, 2031
Zaporizhzhya 3	V-320	950	March 1987	2017, 2032
Zaporizhzhya 4	V-320	950	April 1988	2018, 2033
Zaporizhzhya 5	V-320	950	October 1989	2019, 2034
Zaporizhzhya 6	V-320	950	September 1996	2026, 2041
Total (15)	13,107 MWe net			

Sources: *Öko-Institut, http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/ukraine.aspx,*

Figure 4-1: The Ukraine conflict in the Conflict Barometer and nuclear power plants in the region



Source: (HIIK 2016); map: http://www.insc.anl.gov/pwrmaps/map/info/copyright.php (Status March 2016)

4.2. Financial assistance and international agreements

Seven years after the Chernobyl disaster, a fund was set up at the initiative of the G7 to provide assistance to countries operating obsolete and unsafe Soviet-designed nuclear power plants, the aim being to prevent further accidents. Established by the European Bank for Reconstruction and Development (EBRD) and donors, the Nuclear Safety Account (NSA) primarily supports the decommissioning and dismantling of nuclear power plants in Eastern Europe. The NSA has received a total of € 285 million in contributions from the G7, the European Union, Belgium, Denmark, Finland, Norway, the Netherlands, Sweden and Switzerland alone. More than 40 donors are currently contributing to the NSA. In 1996, it was agreed that the NSA should pay a proportion of the costs of decommissioning and dismantling all the Chernobyl reactors. As an additional measure, the Chernobyl Shelter Fund (CSF) was established in 1997 to finance the construction of the new confinement structure to enclose the ruins of Chernobyl's Unit 4. As of 2015, contributions to the CSF totalled € 2.1 billion.

In addition to the shelter, the clean-up at Chernobyl involves the construction of a new interim storage facility for spent fuel, a new liquid radioactive waste treatment plant (LRTP) and a treatment facility for solid radioactive waste (EBRD 2016).

In 2012, the EBRD and Euratom announced a new financial assistance package for comprehensive safety upgrades at Ukrainian nuclear reactors. The programme will cost € 1.4 billion in total and will enable Ukraine to implement up to 87 safety measures aimed at improving nuclear facility safety. In addition, since the start of the crisis, it is reported that the Ukrainian authorities have been providing more robust physical protection for the country's nuclear facilities against sabotage from outside the facility (BMUB 2014).

Ukraine's energy supply is heavily dependent on nuclear power. It still receives most of its nuclear services and nuclear fuel from Russia, but is reducing this dependence by buying fuel from the US-Japanese conglomerate Westinghouse as well. However, the switch to the Westinghouse fuel elements, which are of a different shape, was reportedly associated with compatibility problems affecting safety at first, not only in Ukraine but also in the Czech Republic, causing deformation of the fuel elements while the reactor was in operation (LN 2014; Halabuk 2014; Sputnik 2012; Heyden 2015).

In March 2015, an agreement was signed by Ukraine's Ukrenergo energy distribution company and Polenergia, a Polish counterpart, to export electricity as part of the Ukraine-European Union "energy bridge", enabling greater use of Ukraine's nuclear capacity and generating funds to pay for the planned increase of capacity at Khmelnitski power plant. Khmelnitski 2 will then be disconnected from the Ukraine grid and synchronised with the EU grid to facilitate future energy exports (WNA 2016).

In its Special Report[9] on EU Assistance to Ukraine, the European Court of Auditors concludes that EU financial support has had only limited impact (ECA 2016). In the related press release (Euractiv 2016), Szabolcs Fazakas, who led the audit, is reported to have admitted that the EU had no chance to analyse whether EU spending in Ukraine had indeed been used for the specified purpose. According to Fazakas, it was possible only to "control that the transfer took place"; the actual use of the funds was not verified in detail. This lack of spending transparency poses problems for the EBRD's activities as well, given its current engagement in Ukraine, and makes the implementation of nuclear safety measures more challenging overall.

[9] Special Report: EU Assistance to Ukraine: "supporting the transformation of Ukraine into a well-governed state in the areas of public finance management and the fight against corruption, as well as in the gas sector during the 2007-2015 period" (ECA 2016).

4.3. Selected nuclear safety incidents in the context of the civil war in Ukraine

The Ukrainian energy supply has been the target of military attacks on several occasions in the current conflict, with adverse consequences for the regions concerned. First and foremost, the supply of electricity from conventional coal-fired power plants has been severely impacted by the civil war. Five large thermal power plants near Donbas now operate at reduced output. As the fighting in the Donbas region also affects coal mining, there are periodic outages due to lack of coal.

A hit on the unit transformer at a Luhansk coal-fired power plant resulted in a fire which put the plant out of action, blacking out a large region. Towns and villages with a total population of about 700,000 had no power, including the major industrial centre of Luhansk. Power grids have also been targeted on numerous occasions (Kovynev 2015). Power lines, transformer and distribution substations have been damaged or destroyed by shelling.

Military units have been deployed to guard Ukraine's nuclear power plant sites from similar hazards (see Section **Fehler! Verweisquelle konnte nicht gefunden werden.**).

In addition to the damage to power grids, the targeted attacks have caused the deaths of grid personnel: a number of employees were shot while inspecting and repairing equipment in outdoor areas of the power plants, transformer substations and the grid itself. Such a situation inevitably causes immense psychological stress for energy industry staff (Kovynev 2015) and this in turn undermines facility safety.

These circumstances create additional challenges for nuclear safety management. With reference to examples from the Ukraine conflict, the following section sets out to show how acts of war, in their many manifestations, can affect the safe operation of nuclear facilities, whether or not these are intentionally targeted.

4.3.1. Damage to the supply line to Crimea

The peninsula of Crimea obtains much of its power supply from the South Ukraine and Zaporizhzhya nuclear power plants, as well as from coal-fired power plants in southern Ukraine.

On 20 November 2015 (HIIK 2016; Sputnik 2015; RT 2015), several electricity pylons forming part of the supply line near Kherson were attacked with explosives, causing a full or partial blackout which affected 1.9 million people in Crimea. An armed group of Crimean Tatars and Right Sector[10] activists then blocked local repair crews' access to the pylons, impeding efforts to restore the line. This was followed by further clashes and, on 21 and 22 November, more explosions which damaged two electricity pylons. After negotiations between the city of Kherson and the activists, the power line was repaired on 8 December, partly restoring the power supply to Crimea (HIIK 2016; Spiegel 2015a; RT 2015).

The perpetrators were probably unaware that the operation of the multi-unit nuclear power plant at Zaporizhzhya would also be adversely affected and ultimately put at risk by their act of sabotage, which resulted in an emergency unloading by 500 MW of both nuclear power plants – a situation described by the national power company Ukrenergo as very dangerous (RT 2015).

[10] Prawyj Sektor (Ukrainian: Пра́вий се́ктор; English: Right Sector) is a far-right Ukrainian nationalist political party with a paramilitary wing.

4.3.2. Attempted seizure of Zaporizhzhya nuclear power plant

In a letter sent to the International Atomic Energy Agency (IAEA) in 2014, Ukraine expressed concerns about “illegal actions of the Russian armed forces on Ukrainian territory” and the “potential consequences for its nuclear power infrastructure” (Süddeutsche 2014).

In fact, an attack came from another quarter: on 17 May 2014, a group of 20 armed Ukrainian activists belonging to the extremist Right Sector attempted to break into Zaporizhzhya nuclear power plant but were detained by security forces. The organisation attempted to justify its actions on the grounds that the plant could fall in the hands of pro-Russian separatists (Global Research 2015).

4.3.3. The downing of Flight MH17

On 17 July 2014, a Malaysian Boeing 777 – passenger aircraft Flight MH 17 – was shot down by a Russian-made missile over Ukraine, crashing near the city of Torez in the Donbas conflict zone, close to the Russian border. There were no survivors. Leaving aside the still contentious issue of the perpetrators’ identity, the Dutch investigators have voiced criticism of the Ukrainian Government, which was responsible for the safety of the airspace:

> *In view of the fighting with rebels in the east of the country, the Government should have closed the airspace. "Nobody gave any thought of the possible threat to civil aviation," said chief investigator Tjibbe Joustra (ARD 2015).*

The aircraft came down around 300 km from Zaporizhzhya nuclear power plant. It is apparent that at the time of the attack, the Ukrainian Government had no control over, nor had it closed, its airspace. This gap in security could have resulted in an aircraft crashing on the nuclear plant or on the grid connection that is, among other things, important for the external power supply of the power plant cooling system. Ein Solches Sicherheitsdefizit hätte auch zu einem Absturz auf das Kernkraftwerk oder auf die Stromnetzverbindung führen können, welche unter anderem für die externe Stromversorgung der Pumpen des Kühlsystems wichtig ist. At present, all airlines are avoiding the airspace over the conflict region, so there is currently no risk of an incident involving any large civilian aircraft here.

In the days that followed, it was difficult to deliver adequate assistance to the crash zone. Investigations were actively obstructed by local conflict parties, and the safety of rescue workers and investigators was not guaranteed. Divergent interpretations of the possible causes of the crash quickly emerged, with the conflict parties engaging in mutual recriminations.

Similar difficulties may be expected to arise at the local level in the event of an attack on, or unintended damage to, a nuclear facility in a conflict region. This in turn can lead to further problems, for example if rapid external assistance needs to be delivered in order to mitigate the impacts of damage to a reactor. Here, the difference between hours and days can be crucial in determining whether an incident is contained and managed effectively or escalates into a major accident.

4.3.4. Fires near the Chernobyl site

In spring and summer 2015, forest fires reportedly raged for several days in the uninhabited exclusion zone[11] around Chernobyl nuclear power plant. In an interview with *Segodnya* newspaper, Vladimir Boreyko, Director of the Kyiv Ecological and Cultural Center, warned: “The

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[11] The exclusion zone extends for several hundred hectares around the ruins of Chernobyl nuclear power plant.

forests are heavily contaminated with radioactive particles which the clouds of smoke may disturb and disperse across residential areas. What's more, some of the burning timber is radioactive" (Epochtimes 2015; Heyden 2015, 2015; Jeglinski 2015). However, the Kyiv authorities countered with the assertion that the fires had not caused radiation levels in the region to rise "above the norm".

At a press conference, the head of the Chernobyl fire fighters' union identified lack of funding for the fire services as the main reason why the forest fires were so extensive and took hold so quickly (Heyden 2015). This lack of funding is symptomatic of the generally precarious state of Ukraine's public finances, for which the civil war is very substantially responsible.

5. Survey on the situation in Ukraine in relation to nuclear safety

An essential component of the project documented here was the survey addressed to interview partners who are currently and/or have previously been engaged with matters of nuclear safety in Ukraine. Those contacted as interviewees were European specialists in the field (individuals or from institutions, some with exclusively technical backgrounds, some with broad energy-policy backgrounds), journalists, environmental activists and personnel employed by operators. The individuals/organisations who made themselves available to answer questions have been engaged with the theme of nuclear safety or with domestic political developments in Ukraine for more than 20 years, and either visit Ukraine regularly and maintain close personal and professional ties in Ukraine or actually live in the country. Out of eight selected individuals/organisations, five completed a questionnaire and/or were interviewed by telephone. Within the scope of the documentation presented here, only extracts from the interviews are given.

5.1. Survey procedure and participants

The survey was carried out in May 2016. The thematic headings and the individual questions in the questionnaires were geared essentially towards the personal backgrounds of the respondents interviewed; the questions were asked in English when this was required. The sets of questions were designed so that part had a common structure for comparison purposes while another part was adapted to the specific background of the given person/organisation. Those interviewed were

- an organisation established in the field of nuclear safety research and an internationally recognised expert specialised in the field of nuclear technology and energy policy,
- two journalists and a female environmental activist, who could offer an all-round perspective on the situation and developments in Ukraine in recent years.

In framing the questions, effort was dedicated to making it possible to differentiate subjective perceptions and sympathies from objective facts and events and incidents. For telephone interviews, the respondents received the questionnaire in advance to enable them to prepare themselves.

The interviews were documented in writing and the responses double-checked with the respondents afterwards. At the evaluation stage, in some cases supplementary material was included, taken from interviews given by the surveyed respondents in the past and relevant articles published in the press.

5.2. Thematic areas and evaluation of the survey

The first set of questions, apart from obtaining basic information about the person/organisation, dealt with their specific specialist background, their ties to Ukraine, and the chronology of their personal experience relative to conditions in Ukraine.

One set of questions addressed the respondents' assessment of how far political or other decision-makers in Ukraine are aware of nuclear safety problems, whether they currently see any need for action, and to what extent they might be capable of realising measures politically.

A few experts were asked about their experience concerning the financing of safety-related nuclear projects and concerning the situation's adverse effects on project work. In that context they were also asked to take a view on the possible deterioration of nuclear safety as a result of a lack of state funding and the impending threat of state bankruptcy in recent years (Spiegel 2015b; Jeglinski 2015; FocusEconomics 2017).

All respondents were asked about their assessment of nuclear safety in Ukraine generally and about the cooperation between operators and the Regulatory Inspectorate.

Another important theme was the identification of various laws that came into being under time pressure and in response to domestic political tensions or foreign policy requirements, and which are negatively affecting nuclear safety although this was nobody's intention.

Research in the media yielded various references to incidents where safety was a relevant concern. Some of these incidents have been discussed in Section 4.3.One set of questions was addressed to these incidents. Furthermore, the respondents themselves mentioned additional incidents and pointed out corresponding reports in the media.

During the interviews, reference was also made to the most recent progress report about Ukraine for the Nuclear Security Summit 2016 in Washington D.C. (Nuclear Summit 2016), particularly in connection with the security and control of "orphan sources" of radiation. As far back as 2009, an analysis of Ukrainian reporting to the Joint Convention[12] revealed that Ukraine did not or could not provide any responses on this issue to the IAEA (Öko-Institut 2009).

5.3. Findings of the survey

The information assembled in this section reflects the opinions of the interviewed experts only. Some passages give verbatim extracts from their responses.

The overall picture painted during the interviews by those questioned primarily drew attention to the increasing vulnerability of the Ukrainian nuclear infrastructure. Generally speaking, the complex nuclear systems are susceptible to faults even under peaceful conditions; in peacetime, however, the framework conditions are stable and the necessary infrastructure is in place for control and the elimination of faults. Given unstable conditions such as those in Ukraine, in contrast, a hazardous combination of chance events or deliberate actions compromising safety seemed far more probable to all respondents.

5.3.1. Correlation of nuclear safety with the political and legal setting

The respondents generally viewed the functionality of the authorities and the infrastructure as severely compromised in the present situation in Ukraine. In term's of the country's existing nuclear

[12] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

infrastructure, this means that the risk of a – potentially also transboundary – nuclear accident has risen massively. On the political level, the respondents consider that decisions are frequently short-term, taken under time pressure and based on practical constraints. Such decisions have a severe (negative) influence on nuclear safety whether or not the decision-maker is necessarily aware of this. One example cited was the political strategy of decoupling from dependence on Russia, which is having negative impacts in the nuclear sector, in particular, since historically this was under Russian influence for decades and the nuclear infrastructure is based on Russian technology. The experts emphasised that this is not meant as a political recommendation for Ukraine to align itself more closely with Russia, but is a statement of fact rooted purely in technical realities.

In this connection the planned switch of fuel-element manufacturer described in Section **Fehler! Verweisquelle konnte nicht gefunden werden.** was also mentioned. In order to become less dependent on Russia in the nuclear field, in future Westinghouse will be manufacturing fuel elements for Ukraine's Russian-designed and constructed reactors. The production of the fuel elements by Westinghouse is feasible, say the interviewed respondents, and there is no fundamental argument against it. However, it will take time for Westinghouse to develop adapted and reliably functioning fuel elements. This is at odds with the political wish to end the dependency on Russian-supplied nuclear fuel as soon as possible. The decision to change the fuel elements supplier rapidly gave rise to short-term practical constraints, which can lead to hasty decisions, in the opinion of those questioned. This is fundamentally problematic because the consequences of wrong decisions are not necessarily immediately identifiable. Fundamental questions in areas relevant to nuclear safety should be addressed independently of short-term constraints.

In this context, the respondents reported on incidents that arose during the attempt to retrofit a Ukrainian reactor with fuel rods from the US firm Westinghouse. In 2015, two incidents occurred in reactors of the South Ukraine facility involving the test fuel elements used there. According to the interviewees' responses, these had to be removed from the reactors immediately due to construction faults (cf. Section **Fehler! Verweisquelle konnte nicht gefunden werden.**). Until now, the State Regulatory Inspectorate has not apparently reached any conclusive decision to license fuel elements manufactured by Westinghouse for commercial use in Ukraine. To dispense too quickly with the original Russian fuel elements and to retrofit an adapted Westinghouse product without careful planning would constitute a heightening of the safety risk, in the view of the experts questioned.

Moreover, a new law "On Licensing of Certain Economic Activities" was mentioned and evaluated in very critical terms. In that context, a comment was quoted from an interview given by the head of the Ukrainian Nuclear Regulatory Inspectorate, Sergej Bozhko, to the German TV channel ARD (Heyden 2015): "the law infringes the independence of the Ukrainian Nuclear Regulatory Inspectorate and constraints the supervisory officials in carrying out inspections". In respect of this law, the respondents explained the following points: in order to comply with International Monetary Fund conditions and to ease burdens on domestic industry, Ukraine had introduced a moratorium on all environmental and other inspections. But this affects the nuclear sector, too. This seemingly came about unintentionally in the nuclear sector and the negative impacts had not been anticipated. Nonetheless, the consequence since then had been that inspections could no longer be instigated by the Regulatory Inspectorate but had to be prearranged with or requested by the operator. The Regulatory Inspectorate has thus lost its independence (which in the respondents' view had been curtailed even beforehand) and is reliant on the good intentions of the facility operators. A similar situation applies to regulatory inspections in other sectors of industry.

Attention was also drawn in the interviews to the problem of interim storage and (lack of) a repository for high-level radioactive waste, especially considering the agreement with Russia for the return of spent fuel elements for reprocessing, which ends in 2018. Criticism was also addressed to the fact that so far (except for Chernobyl) there is no fully formed nationwide concept for the management of high-level radioactive waste beyond the storage ponds in nuclear power plants; the current predominance of wet storage was deemed by the respondents to be highly risky and susceptible to outside interference, and especially attacks.

5.3.2. Radioactive inventory and management of radiation sources

In the view of the respondents, the progress report to the Nuclear Security Summit 2016 (Nuclear Summit 2016) was clearer than the previous report in 2014 in its reporting about the control of orphan sources in Ukraine. The report shows that especially in Ukraine, not only the total radioactive inventory but also the number and distribution of radiation sources are very high.

The control of radioactive radiation sources by state institutions appears inadequate by comparison. There are, however, individuals at various executive levels who do ask questions about the security of radioactive inventories.

The report is also valued as an indicator for general safety issues. Thus, one can draw the conclusion that if the control of radioactive sources is not in place then the status of the governmental Regulatory Inspectorate is also doubtful. All in all, the authorities in Ukraine were obviously finding it difficult to inspect and regulate the safe management of radioactive material.

5.3.3. Adverse effects on nuclear infrastructure and specialist personnel situation, links to financial situation

The respondents expressed serious concerns that the general deterioration of the situation in the course of the civil war is leading to an insidious erosion of safety in the nuclear sector. This increases the probability that multiple causes of damage might cascade and lead to a serious nuclear accident.

To the respondents' knowledge, an economic downturn of about 40% in Ukraine and a corresponding decline in electricity consumption was already evident in the 1990s. It is important to develop an appropriate energy strategy for the future, to adapt it to current demand, and to investigate which bottlenecks would arise if any of the active nuclear power plants were shut down. In order to arrive at a political compromise between energy supply and nuclear safety, it would be necessary to demonstrate objectively which facilities have the lowest safety standard and to decommission these if need be.

The difficult economic situation was seen by the respondents as closely interlinked with difficulties in adhering to nuclear safety requirements. In the view of the nuclear specialists, it was a result of the deteriorating financial situation that not all planned measures could be realised within the time-frame and on the scale envisaged.

In the last 30 years, the respondents have been observing a massive migration of experts from Ukraine to Russia, where better working conditions and payment are being offered. Because the remuneration of operating personnel is very poor, some theft also happens in nuclear facilities. This has no direct bearing on radioactive substances but has indirect repercussions for the safety culture and can compromise this. Specific mention was made of metal objects and insulation materials being stolen, for example. It was repeatedly stressed in the interviews, however, that despite the difficult situation the personnel perform their duties professionally and with the utmost commitment. For historical reasons, the vast majority of employees are originally from Russia or were trained in Russia, yet as far as the interviewed parties know, there are no apparent tensions within the operative personnel deriving from the ongoing civil war.

In this connection, the respondents spoke about a “Lustration Law”, with the help of which “representatives of the old regime” in governmental institutions are being removed from office. On the basis of this new law, the head of the State Nuclear Regulatory Inspectorate, Mikhail Gashev, was dismissed in October 2014. He banned the insertion of fuel rods from the American-Japanese company Westinghouse in Ukrainian nuclear power plants following incidents arising from the use of test fuel elements there (Section 5.3.1 and (Heyden 2015)).

Another matter reported during the interviews was the insolvency of the state operator of nuclear power plants, Energoatom. New fuel elements and other material required to operate, as well as the export of spent elements to Russia, cannot currently be financed. This situation arose following a decision by the Minister of Justice, Pavel Petrenko, who ordered the freezing of the operator’s accounts. The basis for this was a court judgment of August 2011 following a suit by the partner company Ukrelektrovat for payment of debts amounting to five million US dollars.

At the time, the respondents were also critical of delays to the works at Chernobyl: the crisis in Ukraine was contributing directly to these. It is especially relevant for the building of the New Safe Confinement. Should the old sarcophagus collapse before the new shelter is standing, it would stir up large quantities of radioactive dust.[13] The respondents also referred to a comment by Jochen Flasbarth, the State Secretary from the German Ministry of Environment (Heyden 2015), who assessed the hazard from possible collapse of the sarcophagus as a transboundary problem.

5.3.4. Evaluation of nuclear safety incidents

The respondents evaluated the power blackout resulting from the sabotage of a section of the main electricity supply line to Crimea (see also Section 4.3.1) as one of the most relevant events and incidents posing a hazard to safety. The reliability of the diesel supply for emergency power generators is a weak spot in Ukrainian nuclear power plants because both diesel reserves and replenishment of them are very problematic. A prolonged outage of electricity from the public grid would therefore be very hazardous for nuclear power plants, as they would then be reliant on emergency power generators. In the respondents’ view, the currently very unstable situation in Ukraine makes such an incident even more probable since the electricity supply, of all things, is one of the most vulnerable parts of the facility. Should an outage affect not just an electricity pylon but an entire transformer substation, there may be a more prolonged loss of external grid power because rapid replacement of a transformer under the prevailing conditions would be difficult. Under these conditions, the supply of emergency power over a lengthier period of time would be critical.

Theft of radioactive substances that could be used to build “dirty bombs” is relatively easy in Ukraine because, the respondents say, adequate control of the totality of radioactive material has not yet been achieved. Therefore acts of nuclear terrorism aimed at constructing a dirty bomb were seen as another relevant risk in the current situation.

Perceived causes for concern were not only the risk of such an act of nuclear terrorism, but also messages from the highest political levels, such as the comment from the head of Ukraine’s National Security and Defence Council, Oleksandr Turchynov, published in June 2015, that a “dirty” weapon can also be built on behalf of the Ukrainian government if needed (Heyden 2015).

[13] The New Safe Confinement has since been placed in situ, which means that the acute risk has significantly diminished.

Regarding other releases of radioactive inventory, the cooling ponds containing the stocks of spent fuel elements are particularly vulnerable: a targeted attack with armour-piercing weapons might cause a loss of coolant so that heat is no longer dissipated and consequently a fuel element fire may break out. Transports of spent fuel elements were also rated as a vulnerability. In the responses, a few of those interviewed confirmed from personal knowledge the attempt, described in Section 4.3.2, to occupy the Zaporizhzhya nuclear power plant.

The respondents living in Ukraine emphasised that a massive release of radioactivity by third-party interference cannot be ruled out in this situation. It need not necessarily be a deliberate use of weapons with the motivation of causing a nuclear accident; chance "accidents" are equally possible.

5.3.5. Escalation of the conflict from the respondents' view

In the interviews, the respondents expressed great concern that further escalation of the conflict is possible at any time. The respondents commented on the population's perceptions under these conditions based on personal experience and conversations during their time spent in Ukraine. Below, these aspects are included under the most important headings in the way that they were articulated by the respondents.

- Escalation of the civil war

  The readiness of Ukrainian ultranationalists to use violence may increase in the event of political destabilisation and further spread of the civil war in Eastern Ukraine. It cannot be ruled out that if the political crisis in Ukraine intensifies, ultranationalist forces could take control of a nuclear power plant in order to exert pressure on President Poroshenko and other decision-makers. That the ultranationalists are prepared to commit acts of violence against Ukrainian security authorities was demonstrated by the hand-grenade attack outside parliament on 31 August 2015 and by battles with the police in the Western Ukrainian city of Mukacheve in July 2015. The conflict between the Ukrainian army, the security forces and the right-wing nationalist volunteer battalions, on the one hand, and the forces of the (self-proclaimed and not internationally recognised) Donetsk and Luhansk "People's Republics", on the other, may escalate at any time. If the social situation in the southeast of Ukraine deteriorates any further, demonstrations supporting the federalisation of Ukraine are very probable, which in turn implies that these will be put down violently by Ukrainian security forces and ultranationalist radical right-wing groups as a "separatist threat".

- Perceptions within the population

  The population are very torn; some feel like Ukrainians, others identify with Russia. Poverty and corruption are rife.[14] In the years following the disintegration of the Soviet Union, a political caste has formed that is primarily concerned with its own advantage and instrumentalises the country's disunity for its own ends; on top of this comes an entrenched conflict with Russia. There are around one million internal migrants with no prospects of seeing their situation improve. Most people are preoccupied with their own survival and do not give a great deal of thought to other risks, even if there is some theoretical awareness. In the situation right now, the fear that the war will escalate further is greater than the fear of an accident in a nuclear power plant. The energy supply has turned into a major problem and is becoming an existential issue. Therefore people in general take a less critical view of nuclear power. In addition, the nuclear power sector built up

[14] Authors' note: In the current Corruption Perceptions Index (2016), Ukraine is ranked 131 out of 176 states listed: http://www.transparency.org/news/feature/corruption_perceptions_index_2016

over past decades, the associated training of specialists, and the country's own technical know-how have become the symbol of a certain national pride.

5.3.6. The responsibilities and tasks of national policy-makers and the international community, level of media attention

On the one hand, the international community's tasks drew criticism from the respondents in relation to past decisions, while on the other hand, major items of support needed from the international community in future were named and elaborated in more detail.

The interviewees urgently recommended that the international community must act more purposefully. It should recognise and clearly communicate that under the current conditions in Ukraine, control over radioactive materials is very weak and any incident could result in a major release of radioactive substances with transboundary consequences for large parts of Europe. The respondents stressed that the international community must claim its responsibility and change the way in which it deals with Ukraine and Russia, including diplomatically; not least because the past negotiations and diplomatic strategy are showing few signs of success (cf. Chapter 4).

However, respondents were also of the opinion that at present, holders of political responsibility in Ukraine and abroad are conscious of the risks and hazards of a nuclear accident. It was noted positively that the USA and the EU have observers in situ tasked with monitoring nuclear issues. The question of nuclear safety is not addressed publicly by the Ukrainian government for reasons of state and owing to the war in Eastern Ukraine, because the government fears unrest in the population and political destabilisation.

Likewise the disruption of the electricity supply to Crimea by Crimean Tatars and supporters of the "Right Sector" (Section 4.3.1) are being followed with concern. Respondents criticised the minimal coverage of the incident in the German media, and emphasised that the German media generally should make more effort to cover the theme of nuclear safety in Ukraine. In the respondents' opinion, Germany should make far greater use of its influence on the Ukrainian government with a view to urging it to prevent these kinds of violent actions by nationalist forces. The government in Kiev had not firmly condemned the attack on Crimea's energy supply, and in the Ukrainian media the attack was only reported as a "patriotic action".

The respondents saw a danger that the German government, out of a misunderstood sense of solidarity with Ukraine in its conflict with Russia, is not treating the question of nuclear safety with the necessary political pressure.

From the viewpoint of nuclear safety, criticism was levelled at the energy policy strategy of the Ukrainian government, which clings to nuclear energy despite the high-risk environment and favours service life extensions of the ageing nuclear power plants. With the exception of the activities of a few NGOs, the respondents state that no public discussion about the associated risks is taking place. As to whether the competent actors have nuclear safety under control, the answer from the respondents was a clear "no". The State Nuclear Regulatory Inspectorate can only exercise control on a limited scale and its independence is restricted. It is under heavy pressure from the government.

5.4. Summary assessment of the situation in Ukraine

Seen from the perspective of the complex aspects of nuclear accident risks in crisis regions, as set out in Chapter 2, and the current situation in Ukraine, the question that arises is whether the use of nuclear energy in Ukraine is safe by international standards. The impression conveyed by the findings presented here clearly indicates the opposite.

The civil war is contributing heavily to the further destabilisation of a country that has been in serious economic crisis for ten years. The functioning institutional and material infrastructure that is necessary for nuclear safety and the safe operation of nuclear power plants falls short of the requisite scope.

Even ensuring the surveillance and secure management of the large radioactive inventory is a very complex and demanding long-term task, and will remain so in future.

The measures implemented in Ukraine in recent years to improve safety in the nuclear sector were only possible thanks to massive financial support from abroad. Ukraine is, de facto, in no position to do this itself. With the exception of the (at the time of writing) foreseeable completion of the New Safe Confinement over the ruins of the Chernobyl reactor – albeit amid significant delays and immense budget overruns – the investments made so far are showing distinctly less effect than expected, partly because no adequate control could be exercised over the spending of financial support from foreign sources. Widespread poverty has a negative influence and, obviously, so does corruption. Neither the government nor the responsible authorities have the requisite complete control over the radioactive material. The operation of nuclear facilities would appear to need much stronger regulatory supervision than seems possible today. The independence of the Regulatory Inspectorate has been severely restricted.

The financial situation of the operator of Ukraine's nuclear power plants has been deteriorating for years. The pay scales for employees are not being adhered to, and an adequate volume of investment in the usual nuclear safety measures cannot be activated. Contingency reserves are being used up as a result. Personnel are frequently operating at the limits of what is humanly possible to ensure that the nuclear power plants remain in operation.

Evidently large sums "disappear" from international financial assistance without noticeable effect. On the other hand, Ukraine will remain in no position to operate its nuclear infrastructure safely or to upgrade it to improved safety standards without assistance. It follows that international support will continue to be vitally necessary. It is, therefore, a wise and necessary step to establish even closer technical cooperation between the European, Ukrainian and Russian experts to solve the problem and to devise and implement effective measures.

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