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Securing the Resilience of Nuclear Infrastructure against Natural Disasters

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Securing the Resilience of Nuclear Infrastructure against Natural Disasters

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List of Abbreviations

ASEAN	Association of Southeast Asian Nations
ASN	Autorité de sûreté nucléaire (Nuclear Safety Authority)
BEIS	Business, Energy and Industrial Strategy
BNI	basic nuclear installations
CEA	Commissariat à l’énergie atomique et aux énergies alternatives (French Alternative Energies and Atomic Energy Commission)
CNRD	Civil Nuclear and Resilience Directorate
COBR	Cabinet Office Briefing Rooms
DHS	Department of Homeland Security
DOE	Department of Energy
EDF	Electricité de France
ERIA	Economic Research Institute for ASEAN and East Asia
EU	European Union
Euratom	European Atomic Energy Community
FARN	Force d'Action Rapide du Nucléaire (Nuclear Rapid Action Force)
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
GPE	Groupe permanent d'experts (expert advisory committee)
GPU	Groupe permanent d'experts pour les laboratoires et usines (research centre and plant experts standing group)
GPR	Groupe permanent d'experts pour les réacteurs nucléaires (experts standing group)
IAEA	International Atomic Energy Agency
IEEJ	Institute of Energy Economics, Japan
ILL	Institut Laue–Langevin
INPO	Institute of Nuclear Power Operations
IRSN	Institut de radioprotection et de sûreté nucléaire (Institute for Radiation Protection and Nuclear Safety)

ISO	independent system operator
kW	kilowatt
NEA	Nuclear Energy Agency
NEI	Nuclear Energy Institute
NIPP	National Infrastructure Protection Plan
NOPR	notice of proposed rulemaking
NRC	Nuclear Regulatory Commission
OCCTO	Organization for Cross-regional Coordination of Transmission Operators
OECD	Organisation for Economic Co-operation and Development
ONR	Office for Nuclear Regulation
REP	Radiological Emergency Preparedness
RFS	règles fondamentales de sureté (basic safety rules)
RTO	regional transmission organization
SAGE	Scientific Advisory Group for Emergencies
SOG	Standard Operating Guide
SSRP	Sector Security and Resilience Plan
TEPCO	Tokyo Electric Power Company
UK	United Kingdom
US	United States

Chapter 1
Background and Purpose

1.1. Background

Many natural disasters hit Asian countries every year, some of which cause serious damage. A huge typhoon hit the Philippines in September 2018 and a magnitude 7.5 earthquake in Sulawesi Island, Indonesia in October 2018 caused much loss in terms of population and the economy.

Several countries in Asia are considering the introduction of nuclear power to meet the rapidly increasing energy demand. If nuclear facilities are damaged by natural disasters, there is a high risk of more serious damage than from other facilities, such as the release of radioactive materials.

Therefore, promoting information sharing to prepare for natural disasters in nuclear facilities in Asia is extremely important to construct best practices for securing safety and resilience – not only in countries that introduce nuclear power but also in neighbouring countries.

The United States (US), which has the largest nuclear power capacity in the world, and Western European countries have accumulated abundant knowledge of and experience in dealing with natural disasters. Most of this information is accessible at the library of the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD). For example, the Working Group on External Events in the NEA focuses on external hazards of common interest amongst NEA member countries.

Japan, the first OECD member state in Asia, introduced nuclear technology from the US in the early 1960s and has learned a lot about preparing nuclear facilities against natural disasters from advanced countries in Europe as well as the US. It would also be useful for non-OECD Asian countries to learn knowledge, experiences and lessons from the US, European countries, and Japan for considering introduction of nuclear power in the future.

1.2. Purpose

The conditions common to and necessary for securing the resilience of nuclear facilities will be put in order and analysed. The type of actions the operator, central government, and safety authorities in the region should take, as well as the requirements for securing resilience, will be summarised in the policy proposal. Good practices from OECD countries will also be considered for developing the best practice for establishing their nuclear policies in Asia in the future.

1.3. Study Methods

1) Literature Survey

The Institute of Energy Economics, Japan (IEEJ) collected information and analysed the measures taken at nuclear facilities by safety authorities, operators, vendors, suppliers, and engineering experts in nuclear industries in OECD countries against natural disasters.

2) Hearing Survey

The IEEJ has chosen the following countries as the study cases because;

- The US has the largest nuclear power capacity in the world and has experienced varieties of severe natural disasters. After the disaster caused by the hurricane Katrina in 2005, the US reviewed National Preparedness Goal for improving and strengthening national preparedness based on lessons learned from the disaster of the hurricane.
- The United Kingdom (UK) has fewer natural disasters. However, it experienced a large-scale flood in 2007. As a result of increasing attention to the need of critical infrastructure protection, the law structures have been reviewed for incorporation of lessons learned from the flood disaster.
- France experienced an incident at the nuclear power plant (NPP) caused by a flood in 1999. After that, all NPPs in France have been examined their design against flooding and operation instruction under the parliament order. Furthermore, Autorité de sûreté nucléaire (Nuclear Safety Authority: ASN) as part of an inspection of French nuclear industry called on Electricité de France (EDF) for founding of Force d'Action Rapide du Nucléaire (Nuclear Rapid Action Force: FARN) to increase safety after Fukushima Daiichi Nuclear Power Station (NPS) Accident.

The IEEJ made a research visit to the US, the UK, and France, in advance to the workshop (explained in detail later), to interview experts in nuclear-related entities for further analysis and identification of best practices. The issues researched were as follows:

- Review of the abundant knowledge of and experience in measures against natural disasters that the US, the UK, and France have accumulated.
- Review of the measures at nuclear facilities against natural disasters having been taken by safety authorities, operators, vendors, suppliers, and engineering experts in the nuclear industry in the US, the UK, and France.

Based on the above research issues, the IEEJ posed the following questions to authorities, research institutes, and experts in the US, the UK, and France:

- US

・ Regarding the emergency preparedness and response of nuclear facilities to natural disasters, the Nuclear Regulatory Commission (NRC) website states that 'our emergency preparedness programs enable emergency personnel to rapidly identify, evaluate, and react to a wide spectrum of emergencies' and that 'our incident response program integrates the overall NRC capabilities for the response and recovery of radiological incidents and emergencies involving facilities and materials regulated by the NRC or an Agreement State' (NRC, 2018). How have all these programs been constructed, governed, and operated?

- After Fukushima Daiichi NPS Accident in 2011, the Nuclear Energy Institute (NEI) developed a "Guideline for Assessing Beyond Design Basis Accident Response Staffing and Communications Capabilities" (NEI, 2012), outlining the process to be used by licence holders to define and deploy strategies that enhance their ability to cope with conditions resulting from 'beyond design basis' external events. How did they agree to comply with these guidelines?
- In 2017, the US Department of Energy (DOE) started discussions on evaluating the stability and resilience of the electricity system against extreme events, including natural disasters, with numerous related parties. Are these indicators to evaluate the resilience suitable and appropriate? Can they be adapted to Asian developing countries?
- In emergencies, the NRC dispatches expert teams to the site to evaluate the progression of the accident and to verify recommendation to local governments are adequate. How NRC and/or the stakeholders put together their opinions? In Title 10 of the Code of Federal Regulations (CFR) 50 and US Nuclear Regulatory Commission Regulation guidance (NUREG) stipulated the responsibilities and roles of the federal government, local governments, and private companies. However, it is unclear which law stipulates these responsibilities or roles. Which law stipulates these responsibilities or roles (the National Infrastructure Protection Plan (NIPP) or The Sector-Specific Plans)?

- UK

- "The Strategic Framework and Policy Statement on Improving the Resilience of Critical Infrastructure to Disruption form Natural Hazards" (Cabinet Office, 2010b) is primarily directed at central government departments, regulators, relevant public sector bodies, and critical infrastructure owners. It describes the policy intent, scope, aims, work streams, and timescales of the Critical Infrastructure Resilience Programme. How has this program been constructed, governed, and operated?
- "Keeping the Country Running: Natural Hazards and Infrastructure" (Cabinet Office, 2011) is a guide to support infrastructure owners and operators, emergency responders, industry groups, regulators, and government departments to improve the resilience of critical infrastructure and essential services. How did infrastructure owners and operators, emergency responders, industry groups, regulators, and government departments agree to comply with these guidelines?
- The floods in 2007 and more recent events have highlighted the vulnerability of the UK's national infrastructure and essential services. Following such events, the UK has started to build resilience in its infrastructure to reduce its vulnerability to natural hazards. What process to build resilience and state are contributed to public health in the UK, including stakeholder involvement?
  Under the "Revised requirements for radiological protection: emergency preparedness and response" (Government of the UK, 2018), a guide to the Radiation (Emergency Preparedness and Public Information) was established. In emergencies, "the London

Resilience Partnership Strategic Coordination Protocol" stipulates measures based on discussion (London Resilience Group, 2017). Have these measures worked so far, and how has their effectiveness been evaluated?

- The Civil Nuclear and Resilience Directorate (CNRD) in the Department for Business, Energy and Industrial Strategy (BEIS) developed a guide for applicants "Civil Nuclear & Resilience, Candidate Pack" (BEIS, 2017) for recruiting talented, highly motivated people. What are the major responsibilities and roles of the UK Cabinet Office, ministries, and private companies regarding human resource management?

- France

- As parts of inspection of France's nuclear industry following Fukushima Daiichi NPS Accident in 2011, the Nuclear Safety Authority (ASN) called on Electricité de France (EDF) to establish the Nuclear Rapid Action Force (FARN) to increase safety – providing emergency support, in terms of personnel and equipment, at any nuclear power plant in France within 24 hours. How was this program constructed, governed, and operated?

- FARN consists of headquarters in Paris and other offices at NPP sites. How does the operator/supplier put together their opinions? What is the evaluation of this program?

- French nuclear industry experienced flooding at Blayais Nuclear Power Plant in 1999 due to a severe storm. What kind of discussions were raised following the event and what was changed in the Emergency Preparedness and Response Programme?

- In the UK, the Department for BEIS developed a guide for applicants for recruiting talented, highly motivative people (BEIS, 2017). Does the French government have a similar process? If so, which authority deals with it?

- The UK stipulates the responsibilities and roles of the Cabinet Office, ministries, and utilities. Does France designate clear responsibilities and roles for ministries and utilities?

3) Workshop

Energy policymakers and government officials in ASEAN counties and in Japan, experts from the US, and the IEEJ held a workshop on 13th December 2019 to share information, discuss, and identify best practices for measures against natural disasters.

In the workshop, the IEEJ and experts in the US and in Japan provided information on measures taken against natural disasters in OECD countries. Then ASEAN member countries which consider introduction of nuclear power gave presentations about natural disasters in each country.

4) Compiling Best Practices

The IEEJ compiled the best or good practices from the literature survey, hearing survey and the workshop to share with participants to secure the resilience of nuclear facilities against natural disasters, in cooperation with experts in nuclear-related entities in OECD countries.

Chapter 2
Resilience and Measures against Natural Disasters in the US, the UK, France and Japan

The IEEJ has picked up the following countries as the study cases because;

- The US has the largest nuclear power capacity in the world and has experienced varieties of severe natural disasters. After the disaster caused by a hurricane Katrina in 2005, the US reviewed National Preparedness Goal for improving and strengthening national preparedness based on lessons learned from the disaster of hurricane Katrina.
- The United Kingdom (UK) has fewer natural disasters. However, it experienced a large-scale flood in 2007. As a result of increasing attention to the need of critical infrastructure protection, the law structures have been reviewed for incorporation of lessons learned from the flood disaster.
- France experienced NPP incident caused by flood in 1999. After that, all NPPs in France have been examined such as design against flooding and operation instruction under the parliament order. Furthermore, Autorité de sûreté nucléaire (Nuclear Safety Authority: ASN) as part of an inspection of French nuclear industry called on Electricité de France (EDF) for founding of Force d'Action Rapide du Nucléaire (Nuclear Rapid Action Force: FARN) to increase safety after Fukushima Daiichi NPS Accident.
- Japan has experienced varieties of natural disasters as well as ASEAN countries. In 2011, Fukushima Daiichi NPS Accident was caused by Great East Japan Earthquake. After Fukushima Daiichi NPS Accident, Japan has introduced a strict regulation on NPPs for preventing recurrence of nuclear disasters. Thus, lessons learned from Fukushima Daiichi NPS Accident will contribute for ASEAN countries to consider of introduction of NPPs in the future.

2.1. Disaster Mitigation and Emergency Preparedness in the US

2.1.1. Homeland Security Act, 2002

The complexity of US systems and networks is increasing since a significant part of critical infrastructure is operated by private companies while other infrastructures, such as that of government organisations and water-related facilities, is operated by public organisations. The US has concerned about serious damage to Critical Infrastructure caused by large-scale disasters, including increasing terrorist attacks, hurricanes, earthquakes in the Pacific coastal area, and flooding by the Mississippi River.

The 9/11 attack in 2001 revealed homeland security issues, such as the importance of monitoring and deterrence of the development of weapons of mass destruction – including nuclear, biological, and chemical weapons – and the protection of critical infrastructure that supports people's lives. To cope with these issues, the Homeland Security Act was enacted to supplement the organisational inconsistencies, such as a non-integrated command channel of the National Security Agency. The act addressed the entire national security establishment as well as federal government organisations. It is a large-scale law comprising several articles. The protection of critical infrastructure is mainly specified in Articles 201–237 of Part II (Information Analysis and Infrastructure Protection). Matters regarding critical infrastructure are prescribed as follows:

- The authority of the critical infrastructure protection program shall be the President or the Secretary of Homeland Security.
- Protection and operation procedures for disaster mitigation shall be used for important fundamental information submitted to the federal agencies related to the security of important foundations and protection systems to mitigate disaster's impacts.
- Sanctions shall be enforced on entities that perform violative acts.

The Department of Homeland Security (DHS) was established in January 2003 based on the reorganisation of government ministries, aiming at protecting critical infrastructure. It was formed according to the reorganisation of eight ministries and 22 federal government agencies around the anti-terrorism policy. The background of the reorganisation was as follows: the 9/11 attacks stirred up public anxiety about protection of the critical infrastructures against terrorism attacks, which support people's life including finance, energy, communication, health care, transportation, etc., in addition to direct physical damage. Regarding the protection of critical infrastructures, although the Critical Infrastructure Assurance Office was established in the Department of Commerce under President Clinton, people who actually experienced hostile terrorist attacks raised their voices for re-examination of the existing protection system and prompt development of safety enhancement measures (Keiji Tsuchiya, 2004).

2.1.2. Homeland Security Presidential Directive 7

In 2003, the DHS began activities to protect critical infrastructure and key resources and improve their resilience. The directive was a revised version of Presidential Decision Directive 63 on Critical Infrastructure Protection signed by President Clinton in May 1985, which initiated cybersecurity efforts. The Bush administration replaced Presidential Decision Directive 63 with a new critical infrastructure protection policy, led by the DHS when it was established as one of the national security policy packages following the terrorist attacks. Homeland Security Presidential Directive 7 placed the DHS at the centre of all national policies related to critical infrastructure protection. The DHS is required to present the national policy, implement efforts to protect Critical Infrastructure, encourage other federal government agencies to protect Critical Infrastructure in their related fields, and play the role of coordinator for infrastructure related to more than one agency.

To implement the presidential directive, Homeland Security Presidential Directive 7 includes 31 policies to protect Critical Infrastructure from terrorism; and defines the roles of federal ministries and agencies, state governments, and local government agencies. It also specifies 18 Critical Infrastructure fields and requires the development of the NIPP, which protects the country comprehensively from threats such as cyberattacks, physical attacks, and other natural disasters.

2.1.3. National Infrastructure Protection Plan

The first NIPP (DHS, 2006), based on Homeland Security Presidential Directive 7, outlined the risk management plan to protect important national infrastructure. It provided the definition of resilience mainly for Critical Infrastructures. The second NIPP (DHS, 2009) states that the definition of resilience is ‘the ability to resist, absorb, recover from, or successfully adapt to adversity or a change in conditions’. The scope of resilience was extended to the entire Critical Infrastructure. Based on Presidential Decision Directive 21, the third NIPP (DHS, 2013) specified the following 16 sectors as the Critical Infrastructure which was the target of the plan developed by the DHS: chemical; commercial facilities; communications; critical manufacturing; dams; defence industrial bases; emergency services; energy; financial services; food and agriculture; government facilities; healthcare and public health; information technology; nuclear reactors, materials, and waste; transportation systems; and water and wastewater systems.

Implementation items specified in the NIPP are as follows:

- Promote understanding and information sharing about terrorism and other threats.
- Establish the partnership required for information sharing and implementation regarding the improvement plan for the protection of Critical Infrastructure and resilience.
- Implement the following items to perform the long-term management program:
  - Reinforce, distribute, and enhance the resilience of Critical Infrastructure against every threat and emergency.
  - Develop prevention measures against human-made attacks.
  - Develop countermeasure plans to cope promptly with breakdowns in critical infrastructure or instability; and keep the influence on public health, security, the economy, and government functions as small as possible.
  - Develop a plan to promptly restore the functions of Critical Infrastructure. Make the best use of the resources relating to the protection of Critical Infrastructure.

2.1.4. Sector-Specific Plans

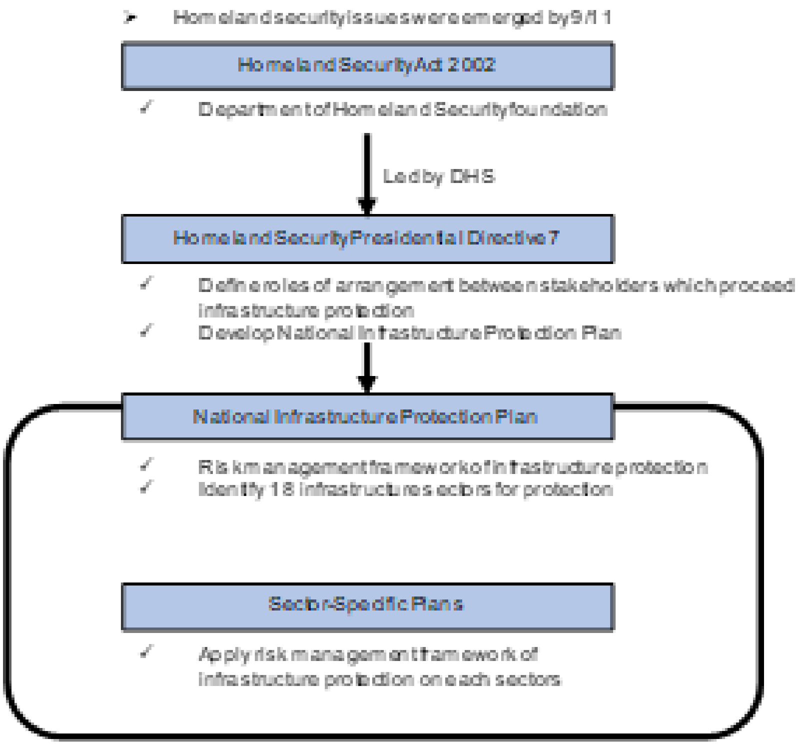
The sector-specific plans apply the risk management framework described in the NIPP to the characteristics and risk environments of each Critical Infrastructure sector (DHS, 2019a). The plans were compiled based on discussions amongst the main agencies of each Critical Infrastructure sector, and organisations and companies in each industrial sector, with the support of the DHS. Government organisations and infrastructure companies have implemented strategies and countermeasure plans to prepare for threats, in accordance with the plans for each sector.

Plans in each sector are integrated according to the following items:

- Characteristics and objectives of each sector
- Identification of resource, system, network, and function
- Risk assessment
- Priority of infrastructure
- Development and implementation of protection program
- Evaluation of process
- Research and development related to the protection of Critical Infrastructure
- Management and coordination of the responsibility by the administrative agency

The Nuclear Reactors, Materials, and Waste Sector of Sector-Specific Agencies (SSA) in the DHS is responsible for the coordination of security and resilience regarding the nuclear sector (CISA,2013). The Nuclear Reactors, Materials, and Waste Sector sector-specific plan (DHS, 2019b) cover most of the US civil nuclear infrastructures and details of how the risk management framework of the NIPP is implemented for characteristics specific to nuclear power.

Figure 1: Legal Structure of US Nuclear Sector



DHS = Department of Homeland Security, US = United States.
Source: Author, based on DHS (2019a) etc.

2.1.5. Recent Resilience Trends of Individual Government Departments and Agencies

1) **Staff Report to the Secretary on Electricity Markets and Reliability**

The DOE summarised the results of a 60-day investigation directed by DOE Secretary Rick Perry via a memorandum on 14 April 2017 (DOE, 2017b). In this report, the DOE staff emphasised that the market should be changed to provide adequate compensation for reliability. It stated that many power-generating technologies have encountered fuel supply issues and recommended that on-site storage of fuel for power generation should be considered. It also pointed out that the profitability of conventional base-load power stations has decreased since the wholesale electricity market price has declined. The reasons for the decrease in price include a decline in gas prices in the US because of shale gas and the mass introduction of renewable energy (Atomic Industry Newspaper, 2017).[1]

2) **Directions on Federal Energy Regulatory Commission (FERC) from DOE Secretary Perry to provide support to nuclear power plants to maintain the resilience of the power grid on 29 September 2017.**

Secretary Perry stated that nuclear and coal-fired power generation would contribute to maintain resilience even if the fuel supply stopped due to natural disasters. To support these power plants at risk of early closure, he made a proposition that prescribes total cost recovery to FERC, which has independent status within the DOE, and directed it to institute a rule for that purpose (DOE, 2017a).

i) Basic understanding

Resilience of electric power grid is critical for the economy and security in the US.

ii) Availability and necessity of base-load power stations during a polar vortex

According to DOE, many conventional base-load power stations are confronting closure. It also pointed out that 4.666 million kilowatts (kW) of NPPs have been closed from 2002 to 2016 due to the low market price (DOE, 2017b).

During a polar vortex (a record decline in temperatures) in 2014, the effective use of coal-fired power plants that were slated for closure and a high operational rate (95%) of nuclear power plants contributed to satisfy the power demand. It is impossible to operate base-load power stations again once they have been closed although they would contribute to extreme weather such like a polar vortex.

[1] Renewable energy generation facilities have an incentive to continue power generation even if the market price declines to below the break-even level since they can receive a production tax exemption in proportion to the amount of power they generate.

iii) Problems in the wholesale electricity market

In the current wholesale electricity market, the power facilities that ensure power system resilience do not offer enough value.

iv) Excerpt from DOE Staff Report

- A comprehensive and long-term strategy is required to ensure the reliability and resilience of electric power systems in the context of continuous closures of traditional base-load power stations.
- States and civil society organisations are recognising the increasing threat to the reliability and resilience of electric power distribution.
- Hydropower stations, nuclear power plants, coal-fired power plants, and gas-fired power plants provide essential reliability services.
- Ensuring fuel supply is essential to the resilience of power systems.
- It is necessary to continuously check the validity of the domestic electricity supply portfolio from the viewpoint of ensuring the reliability and resilience of the power system.
- The market for assessing the reliability and resilience should be promptly developed.

v) Rules proposed to maintain the resilience of the power system

There are rules to ensure recovery of the cost of fuel-secured power stations to keep the reliability and resilience of power systems.

Target power stations should satisfy the following requirements:

- Be located in a control area of an independent system operator (ISO) or regional transmission organization (RTO).
- Services should be available to maintain the reliability of electric quality such as the frequency and voltage.
- Fuel supply for 90 days should be ensured in the power station for natural disasters such as a polar vortex, human-caused disasters, and abnormal weather such as hurricanes.
- All the environmental regulations should be observed.

For the market controlled by ISO or RTO, preparing a fair and reasonable rate sheet is mandatory and enables providers to collect the total cost and set adequate profit rates.

2.1.6. Announcement of enactment proposal for Grid Resiliency Pricing Rule is posted in the Federal Register (10 October 2017)

The DOE posted a notice of proposed rulemaking (NOPR) in the Federal Register, in which it directed FERC to take final action for the enactment of rules within 60 days from the date on which the NOPR was posted in the Federal Register (Federal Resister, 2017).

1) Views of NOPR Supporters

Representative views of supporters are summarised in the NEI public comments. The following is the public comment of NEI submitted to FERC on 23 October 2017. An outline of the public comments of NEI against NOPR.

A problem is found, and prompt actions are required as follows;

- The problem is that the market under the control of the RTO cannot assess the value of nuclear power plants and they are forced to be closed.
- Closing one nuclear power plant results in the loss of thousands of highly skilled and highly paid workers, along with the loss of zero-emission power stations.
- The 2014 polar vertex reminded us of the necessity of resilience.
- At the time of the polar vertex, 35 million kW of power generation capacity were unavailable, which is 22% of the total power generation capacity in the PJM Interconnection (PJM)[2] district; however, the NPPs maintained a capacity factor of 95%, which is the same rate as in normal operating times.
- The polar vortex reminded us of the importance of the diversity of fuels and the reliability and resilience of the power systems and made us understand that it was a country-wide problem.

The market under the control of the RTO cannot assess the resilience and diversity of power stations. Hence, FERC has to direct the RTO to assess these points.

- The electricity market of the RTO is essentially a short-term market.
- The electricity market of the RTO arranges per-hour electricity, but it does not provide a long-term perspective for electricity procurement.
- The capacity market provides short-term (1–3 years) capacity procurement but does not consider the configuration of power stations, since it is designed not to ask about the type of power generation.
- In regulated states, several state governments develop plans for integrated power generation configuration, but integrated power generation configuration are not considered in deregulated states.

Resilience should be able to cope with practical and emergent needs.

- Reliability is defined as the concept to minimise the loss or interruption of electricity supply to customers, while resilience is defined as the ability to avert the disruption of operation and restore the operation to its ordinary state as soon as possible.
- Fuel diversity is a component of resilience.
- Diversity of power stations enables offsetting the risk of price fluctuations and avoids loss of electricity supply.

Nuclear power plants contribute to resilience.

- A market that excessively depends on one type of fuel is exposed to extreme fluctuations in fuel costs and loss of fuel supply.
- Nuclear power plants enable on-site storage of fuels and continuous operation from 18 to 24 months after reloading. Even if reloading of fuels is prevented, the plants can operate for 3 months at 70% output and then for 2 months at 50% output.

[2] PJM Interconnection is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia.

- The fuel cost of nuclear power plants is low, and its fluctuation is small.
- The capacity factor of nuclear power plants is as high as 92% and stable.

NOPR analysed problems.

- There is no evidence that the fuel supply amount for 90 days is useful to keep the resilience of power systems.
- The conditions for plant closures are not specified.
- The NOPR pointed out that the pricing system of the electricity market is the only factor behind closing coal-fired power plants and nuclear power plants, but other factors – such as state government policies, federal environmental regulations, and the emergence of low-cost fuels – also contribute to such closures.
- During the polar vortex, several coal-fired power plants experienced conveyor failures and coal storage yards were unavailable due to freezing; nuclear power plants also experienced some restrictions.

PJM addressed market environmental change.

- In the PJM district, reliability is maintained by taking advantage of the capacity market.
- Higher power system stability could be achieved in the longer term with technical innovations in a competitive market.
- A power system configuration with higher resilience could be achieved through a diversified energy mix.
- PJM is responding appropriately to recent changes in the market environment, but the NOPR's points do not assess these efforts.

2) Final decisions on DOE NOPR by FERC (8 January 2018)

In January 2018, FERC decided to terminate the enactment of the proposed rules since they do not have concrete evidence based on the Federal Power Act, 2018 (FERC, 2018a). It announced that it was starting a new procedure about the resilience of power grid systems and was terminating the procedure about DOE NOPR. In its statement, FERC announced that it terminated the study of the proposal of 29 September 2017 by DOE (Docket No. RM18-1-000), assigned higher priority to resilience, started a new procedure (Docket No. AD18-7-000) on 8 January 2018, and would verify the resilience of the power grid systems in chronological order. FERC directed the RTO to provide information required to study the necessity of additional measures, which should be taken by FERC or the market, for the resilience of power grid systems in the new procedure. The following is an outline of the statement and the direction of FERC (FERC, 2018b).

FERC announced the outline of the statement.

- Terminates the study of the proposition (Docket No. AD18-7-000) submitted on 29 September 2017 by DOE.
- FERC assigns higher priority to resilience, starts a new procedure (Docket No. AD18-7-000) on 8 January 2018, and verifies the resilience of the power grid systems in chronological order.

- FERC directs the RTO to provide the information required to study the necessity of additional measures which should be taken by FERC or the market, for the resilience of power grid systems in the new procedure.
- Each RTO/ISO shall provide the requested information within 60 days of the ordered date. Any interested agencies are allowed to submit reply comments within 30 days of the submission deadline of the RTO/ISO.

2.1.7. Response of DOE to the Final Decision of FERC (8 January 2018)

The Secretary of the DOE replied to the final decision of FERC. He showed his appreciation to FERC for the investigation of resilience to be started and expressed his intention to cooperate with FERC to promote efforts and nationwide discussions on resilience activated by the DOE/NOPR (DOE, 2018).

- Rick Perry, Secretary of Energy of the United States stated as follows;
  I appreciate FERC for its efforts in performing a further assessment on distortions of the market which expose the long-term resilience of the power grid to risks. As I expected, our proposition this time created nationwide discussions on the resilience of the power grid systems. There is no doubt that securing diversity in fuel supplies, especially on-site fuel supplies, is important to keep electricity supplies at an appropriate price when some weather-related problems occur that we are just encountering now. I hope FERC and DOE will promote efforts to secure sound electricity grids in the future.

2.1.8. Definition of Resilience

In the discussion regarding the DOE NOPR, the definition of resilience is a point of dispute. Supporters of the DOE NOPR claim in public comments that reliability is defined as the concept to minimize loss or interruption of electricity supply to the customers while resilience is defined as the ability to avert corruption of ordinary operation and restore the operation to the ordinary state as soon as possible and emphasise that resilience and reliability are distinct concepts. On the other hand, the opponents of the DOE NOPR claim that resilience and reliability are synonymous concepts that cannot be distinguished from each other, so both can be ensured by continuing efforts to improve reliability without specific efforts aiming at securing resilience.

In Docket No. AD18-7-000, FERC expressed its opinion that no common understanding had been formulated regarding the definition of resilience, then announced the definition of resilience by FERC, asked the RTO/ISO if it needed to be altered, and asked for amendment proposals if any alteration was required.

The opinion expressed by each RTO/ISO in the information provision only showed agreement or disagreement with FERC's definition or made light alterations. The discussion was less active compared with the discussion on the pros and cons of the DOE NOPR, in which the definition of resilience was recognised as an important point.

Although each RTO/ISO basically agrees on the definition by FERC, there are some differences in detail. While the New York ISO (NYISO) expressed its opinion that resilience and reliability often represented the same concept, PJM basically followed FERC's definition but added minor alterations from the viewpoint of workers, as the RTO.

1) Requests from the RTO/ISO to FERC to secure resilience

While PJM and Midcontinent ISO requested FERC to secure resilience, other RTO/ISO members answered that the countermeasures under consideration in each agency were sufficient and had no requests to make to FERC.

A number of entities expressed the need for market reforms (improvement of the wholesale electricity market, capacity market), enhancement of the fuel supply system, reinforcement of transmission/distribution capabilities, and emphasis of these points in the information provision of each agency.

As described above, each agency's requests are similar and small in number, but the opinions of PJM and ISO New England (ISO-NE) have different characteristics from the rest.

PJM focused on the approach through market reforms and explained its idea for improving the wholesale market system under consideration. In addition, it requested FERC to direct each RTO and ISO (and transmission operators operating in areas outside the RTO district and regulated by FERC) to submit their market reform plan and related compensation mechanism to cope with the considerations on resilience within 9–12 months.

ISO-NE pointed out that both the electricity and heating sectors were increasingly dependent on natural gas and the biggest resilience issue is to secure fuel. The opinion presented by ISO-NE is common to the issues recognised by the DOE in the NOPR, in that a resilience challenge may occur because of increasing dependency on gas-fired power generation.

The opinion of ISO-NE is partially common with the opinion of the DOE that claims protection of the base-load power stations. Because it does not exclude, in certain cases, the actions required to maintain facilities against the risks of fuel security. ISO-NE considers actions such as facility maintenance as temporary until guaranteed fuel procurement and supply or enhancement of supply- or demand-side infrastructure are implemented and the root cause of fuel transportation restrictions is resolved, while the DOE intends to introduce overall cost rule for the base-load power stations as a permanent measure.

2) Responses of PJM to the information provided from RTOs/ISOs to FERC (May 2018)

In its comments on 9 May 2018 (PJM, 2018), PJM stated that initiatives which enhance the resilience of transmission systems should not be separated at the boundary of each RTO/ISO, while it respected the opinion of the RTOs/ISOs that intended to adopt individual standards and approaches regarding resilience issues. It reserved judgment on how each local area worked on specific issues but claimed that direct study by FERC was necessary and advocated mixing individual approaches in each area with FERC's comprehensive approach. PJM also pointed out that individual efforts by each local area were required and pointed out the fuel security and Gas-Electric Coordination as the challenges that PJM took measures.

Fuel security. ISO-NE cooperates with local stakeholders to implement specific policies and requests FERC to permit continuous implementation of the policies. California ISO (CAISO) states that each RTO/ISO requires an individual mechanism specific to each area, while it agrees that there may be comprehensive approaches. PJM concerns if fuel security issues have any influence on the reliability and resilience of the large-scale power system in the PJM district. PJM started to analyse fuel security vulnerability and develop assessment criteria for PJM districts.

Gas–electric coordination. PJM has implemented resilience operations which can contribute both to the gas pipeline industry and PJM beyond the concept of reliability, through cooperation with the gas pipeline industry. While information sharing and communication procedures have been established between PJM and the gas pipeline industry, PJM recognises that not enough communication has been established between some parts of the pipeline industry and the RTOs/ISOs and considers this situation as a problem. Hence, it recommends FERC to establish rules that promote open communication for Gas–Electric Coordination (PJM, 2018).

3) Trend of Trump administration and response of each interested party (June 2018)

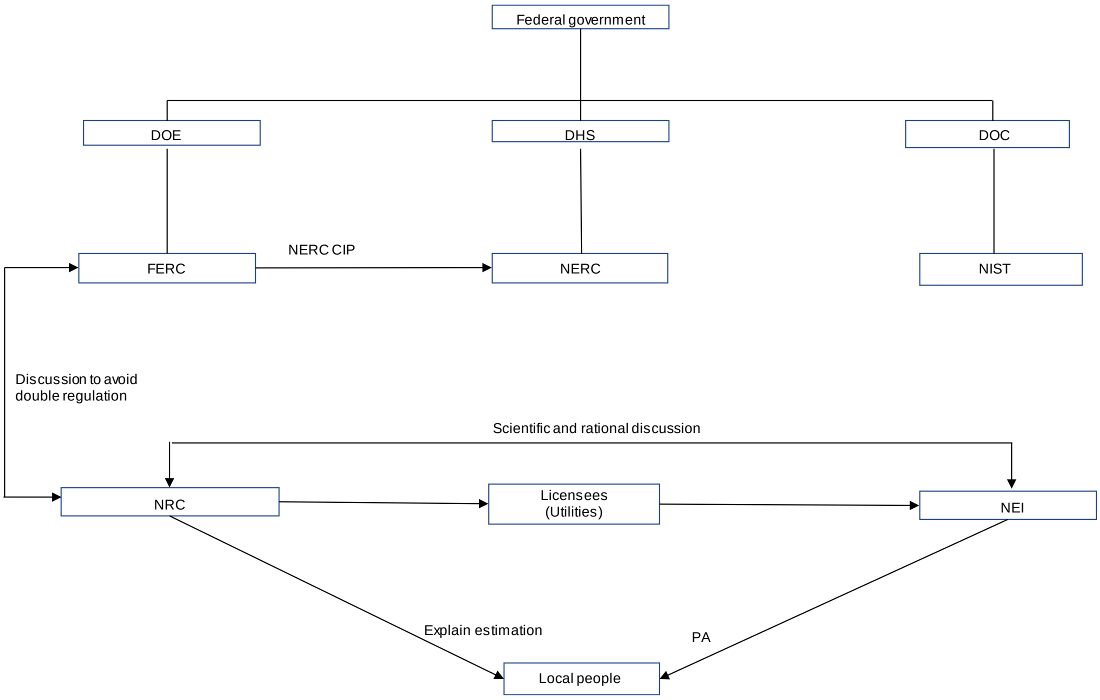
In 2018, White House stated that maintaining infrastructure and the energy supply network in a robust and secure state leads to national security, public safety, and protection of the economy from intentional attacks and natural disasters. It asserted that power generation facilities in which fuel can be stocked are indispensable for the energy mix, so rapidly closing them one after another may affect the resilience of the energy supply network. It requested DOE Secretary Perry to prepare measures to prevent such situations from occurring. Although it was not explicitly mentioned, the sentence "power generation facilities in which fuels can be stocked" is commonly understood to mean coal-fired and nuclear power plants (Mufson, 2018). Following the White House announcement (White House,2018), the NEI released a comment that they welcomed the Trump administration since it recognised the roles of nuclear power in the resilience of energy supply network and national security and was considering measures to handle the early closure of plants. NEI also explained that operations could not be resumed once nuclear power plants began decommissioning procedures and emphasised the importance of fuel storage in the power plants for national security (Japan Atomic Industrial Forum, 2018).

White House (2018) did not cite specific measures, but a memo for the National Security Council containing the measures was leaked on the same day. The memo presented a plan in which the DOE exercises the emergency situation authority prescribed in the Federal Power Act and Defence Industry Act, 2018 to impose on RTOs/ISOs the duty to purchase power generation capacity and electricity preferentially for 2 years from power plants which are at risk of closure; meanwhile, the DOE implements comprehensive analyses and specific actions to maintain the resilience of the energy supply network. According to Mufson (2018), the CEOs of Murray Energy Corporation and FirstEnergy Corp., who were deeply involved in the Trump administration, had suggested such a plan, and the power plants to be supported were owned by President Trump's supporters in the coal industry.

FERC chair Kevin McIntyre stated that FERC would not distort the market. However, after the DOE memo was leaked, McIntyre said the leaked memo was nothing more than a 'draft addendum' and no actions would be taken provided that no specific case was presented (Platts, 2018). McIntyre also stated that it was not adequate to exercise the emergency authority rights.

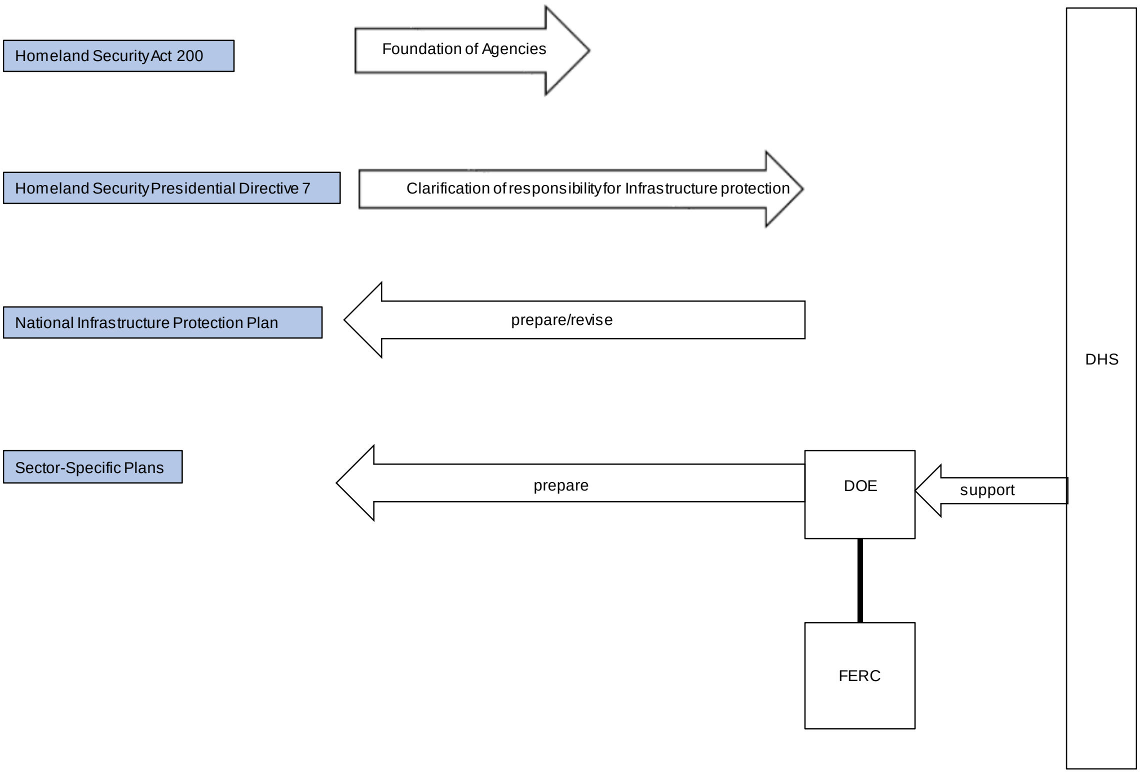
Environmental groups, natural gas producers, and Republicans and Democrats who have promoted competition in the electricity market have criticised the Trump administration for forcibly carrying out the DOE plan. Interested parties in critical positions have pointed out that a number of power stations are in operation longer than the period initially planned, and that preferential treatment for these stations is problematic since it is not only harmful to the environment and forces people to purchase 'dirty energy' that may endanger their health, but also gives certain energy producers favourable treatment politically.

Figure 2: Organisational Chart of Nuclear Power Plants in the US



DHS = Department of Homeland Security, DOC = Department of Commerce, DOE = Department of Energy, FERC = Federation Energy Regulatory Commission, NEI = Nuclear Energy Institute, NERC = North American Electric Reliability Corporation, NIST = National Institute of Standards and Technology, NRC = Nuclear Regulatory Commission, PA = Public Acceptance , US = United States.
Source: Author referenced from DOE, DHS, FERC, NRC etc. https://www.ferc.gov/ (accessed 20 December 2019).

Figure 3: Organisational Structure of National Infrastructure Protection



DHS = Department of Homeland Security, DOE = Department of Energy, FERC = Federation Energy Regulatory Commission.
Source: Author referenced from HP of the US Department of Homeland Security, etc. https://www.dhs.gov/ (accessed 20 December 2019).

2.2. Disaster Mitigation and Emergency Preparedness in the UK

2.2.1. The Pitt Review

In August 2001, the UK government published a discussion document on the future of emergency planning in England and Wales regarding the legal framework of civil protection during emergencies. The document highlighted the following issues:

- For civil protection, no collaboration has been promoted amongst the national government and local authorities, private companies, and non-profit organisations.
- The response to newly emerging situations, such as a spike in oil prices and frequent occurrence of floods, is not adequate.
- Consideration is required for human rights in emergency situations.

This formed the basis of the Civil Contingencies Act, enacted in November 2004, which consists of three parts: (i) local arrangements for civil protection – making civil protection activities and advance plans obligatory for local authorities, among others; (ii) emergency powers – enhancing the emergency powers of the national government during emergencies, and (iii) general provisions. Articles 2–4 of Part 1 on contingency planning prescribe the obligations of operators that provide support to local authorities, and critical infrastructure.

The Civil Contingencies Act was planned to be reviewed within 3 years of its enactment. Following flood damage in central England in the summer of 2007, the Cabinet Office asked Sir Michael Pitt to develop a comprehensive report on the issues that should be worked on in the UK from the viewpoint of a third party. The Pitt Review contains 92 recommendations on the flood risk measures that should be taken by the government and private companies (Pitt, 2008). Recommendations on the protection of critical infrastructure are as follows:

- It is necessary for the government to promote the development of long-term flood measures and laws looking 25 years ahead.
- The government and infrastructure companies must understand and cope with the vulnerability and risk of critical infrastructure.
- The government has to impose on the operators of lifelines and critical infrastructure the duty to develop a business continuity plan that conforms to UK standard BS25999 on business continuity management and periodically check its effectiveness.
- The government has to add roles of emergency response for the operators that provide support for the lifelines and critical infrastructure.
- Local authorities have to cooperate with related agencies to promote the flood risk management and response plan in their districts.
- Emergency response organisations (fire stations, etc.), local authorities and operators that provide support for the lifelines and critical infrastructure have to check the emergency response plan for effectiveness.

2.2.2. Sector Resilience Plan for Critical Infrastructure 2010

The Pitt Review heightened the awareness of the need for protecting critical infrastructure in the UK government. The government created the Natural Hazards Team in the Civil Contingencies Secretariat of the Cabinet Office and began the Sector Resilience Plan for Critical Infrastructure 2010. It published the Strategic Framework and Policy Statement on Improving the Resilience of Critical Infrastructure to Disruption from Natural Hazards (Cabinet Office, 2010b) as the framework for the programme in March 2010.

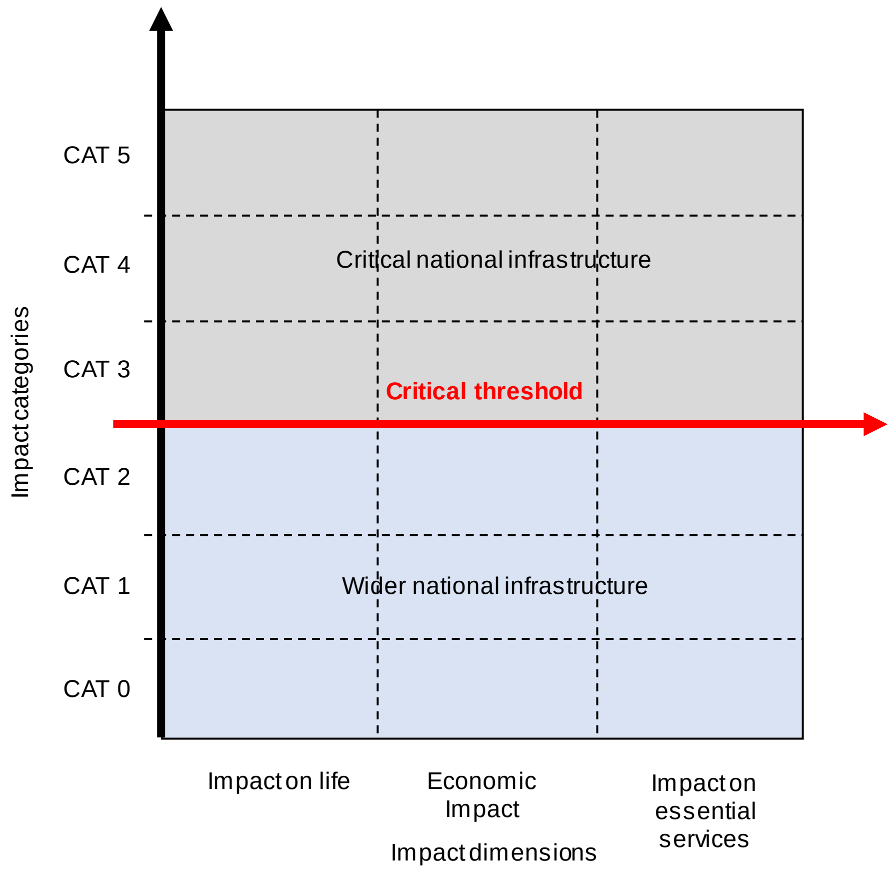
The purpose of the Critical Infrastructure Resilience Programme is as follows:

- Provide the framework to share the analysis of the critical infrastructure and resilience improvement plan for cross-sectoral activities.
- Improve the consolidated capabilities of critical infrastructure to mitigate the impacts of emergencies and take actions promptly.
- Promote effective emergency response at the local level through sharing the provision, response, and restoration information for emergencies.

2.2.3. Categorising infrastructure and the criticality scale

The Strategic Framework and Policy Statement (Cabinet Office, 2010b) described the categorisation of infrastructure (Figure 4) and the criticality scale (Table 1). Infrastructure is categorised as critical if the impact suffered is applicable to category 3 or higher of one of the three impact dimensions: impact on life, economic impact, or impact on essential services.

Figure 4: Three Dimensions of the Criticality Scale



CAT = category.
Source: Cabinet Office (2010b).

Table 1: Criticality Scale for National Infrastructure

Criticality Scale	Description
CAT5	This is infrastructure the loss of which would have a catastrophic impact on the UK. These assets will be of unique national importance whose loss would have national long-term effects and may impact across a number of sectors. Relatively few are expected to meet the Cat 5 criteria
CAT4	Infrastructure of the highest importance to the sectors should fall within this category. The impact of loss of these assets on essential services would be severe and may impact provision of essential services across the UK or to millions of citizens
CAT3	Infrastructure of substantial importance to the sectors and the delivery of essential services, the loss of which could affect a large geographic region or many hundreds of thousands of people
CAT2	Infrastructure whose loss would have a significant impact on the delivery of essential services leading to loss, or disruption, of service to tens of thousands of people or affecting whole counties or equivalents
CAT1	Infrastructure whose loss could cause moderate disruption to service delivery, most likely on a localised basis and affecting thousands of citizens
CAT0	Infrastructure the impact of the loss of which would be minor (on national scale).

CAT = category, UK = United Kingdom.
Source: Cabinet Office (2010b).

2.2.4. Resilience plans

Two types of objectives are defined for the resilience programme of critical infrastructure: (i) short-term and (ii) medium- to long-term. The short-term objective is to identify infrastructure vulnerable to floods and implement countermeasures to prevent damage. In March 2010, Sector Resilience Plan for Critical Infrastructure 2010 was published as the intermediate measures.

The medium- to long-term objective aims at improving the emergency response capability for all critical infrastructure; and contains reviews of existing rules, etc., new enactment of required regulations, and new planning of required policies, etc. Risks and threats that can have significant impacts on critical infrastructure are analysed for their vulnerability and countermeasures are implemented to mitigate the risks on critical infrastructure.

1) Sector Resilience Plan for Critical Infrastructure

The Sector Resilience Plan for Critical Infrastructure set nine Critical Infrastructure sectors (communication, emergency services, energy, financial services, food, government, health, traffic and transportation, and water) and analysed and explained the following items for each sector:

- Critical infrastructure in each sector
- Impacts of floods and high tides on Critical Infrastructure in each sector
- Countermeasures already implemented to minimise the impact of floods on the Critical Infrastructure
- Countermeasures that have to be implemented for the Critical Infrastructure in each sector to prepare for a flood level which is expected to occur once in 200 years

2) Sector Security and Resilience Plan

The Sector Resilience Plan for Critical Infrastructure 2010 (Cabinet Office, 2010a) was limited to preventing flood damage to vulnerable infrastructure. The scope of the plans was enhanced to the Sector Security and Resilience Plan (SSRP) to cover all hazards and security threats related to each sector in 2015-2016 (Cabinet Office, 2016). Since then, the government has issued unclassified SSRPs every year to improve the security and resilience of each sector.

The SSRPs define the UK's Critical Infrastructure as:

> Those critical elements of infrastructure (facilities, systems, sites, property, information, people, networks and processes), the loss or compromising of which would result in a major detrimental impact on the availability, delivery or integrity of essential services, leading to severe economic or social consequences or to loss of life (Cabinet Office, 2019, p.5).

SSRP 2018 also specifies 13 sectors – chemicals, civil nuclear, communications, defence, emergency services, energy, finance, food, government, health, space, transport, and water – as Critical Infrastructure. The relevant sector departments and agencies are listed in Table 2.

Table 2: Sector Departments and Agencies

Sector	Departments and Agencies
Chemicals	Department of Business, Energy and Industrial Strategy
Civil nuclear	Department of Business, Energy and Industrial Strategy
Communications	Department for Digital, Culture, Media and Sport Department of Business, Energy and Industrial Strategy
Defence	Ministry of Defence
Emergency services	Department of Health and Social Care Department for Transport Home Office
Energy	Department of Business, Energy and Industrial Strategy
Finance	HM Treasury
Food	Department for Environment, Food and Rural Affairs
Government	Cabinet Office
Health	Department of Health and Social Care
Space	UK Space Agency
Transport	Department for Transport
Water	Department for Environment, Food and Rural Affairs

UK = United Kingdom.
Source: Cabinet Office (2019).

3) Civil nuclear sector

The nuclear sector's resilience to major risks is ensured through high build standards, a stringent regulatory regime, and effective governance.

i) Assessment of existing resilience

The latest Chief Nuclear Inspector's Report (ONR, 2019), issued by the independent Office for Nuclear Regulation (ONR)[3], and concluded that the nuclear sector in the UK satisfied the safety and security criteria required for its operation. By cooperating with the ONR and the Civil Nuclear Constabulary, which is the armed police force in charge of protecting civil nuclear sites and nuclear materials in England, Scotland and Wales, the civil nuclear sector has adopted all risk approaches necessary for the safety and security of its sites. The civil nuclear sector is required to observe the following national criteria:

- Safety: UK nuclear sites have a legal responsibility for ensuring nuclear safety on their sites and are held to account by a robust licensing system.
- Security: All UK nuclear sites have an up-to-date approved Nuclear Site Security Plan and meet the standards of security required by the regulator.
- Safeguards: The UK's obligations concerning the reporting and/or publication of safeguards related information must be met.

ii) Building of resilience

The Department for BEIS has been cooperating with the government, the ONR and industry to develop a national framework for a contingency plan and a national strategy for nuclear facilities in the UK.

A summary of the national framework is as follows:

- Coordination shall be performed with all interested parties related to this business throughout the UK.
- High-quality and well-tested emergency response and recovery plans shall be implemented for existing and new facilities.
- Efficient and reliable communication shall be conducted with people in local areas, the UK government, and overseas.

[3] Reference: ONR was established in April 2011 through the reorganisation of the Office for Nuclear Installations Inspectorate (NII), which was under the Health and Safety Executive. In 2013, ONR became an independent agency under the Department of Energy and Climate Change (at that time) and in 2014 became an independent statutory public body as a regulatory organisation of the UK. In 2014, ONR published a revised version of the Safety Assessment Principles for Nuclear Facilities, considering the lessons learned from Fukushima Daiichi NPS Accident (ONR, 2014). The purpose of the Safety Assessment Principles is to provide inspectors with a framework to make consistent decisions about safety.

4) Energy sector

The energy sector consists of the upstream of the oil/gas sector and the downstream of the oil/gas/electricity sector. Each sector has made certain investments consistent with its business to create resilience against major risks, although the type of infrastructure resilience and the business environment are different based on the sector.

i) Assessment of existing resilience

Major risks in the energy sector are storms and gales, floods, accidents and loss of key staff. Since reducing all these risks is not cost-effective or feasible, the government, regulators and industry that supplies energy must reduce the supply risks through cooperation. To ensure resilience against the above risks and other risks, energy-related companies do the following:

- Adopt an all risks approach: Under the Utilities Act, 2002, the Office of Gas and Electricity Markets introduced performance levels for the gas and electricity industry, including supply restoration timescales; and the Office of Gas and Electricity Markets' 'RIIO' (Revenue = Incentives + Innovation + Outputs) performance standard for network companies' price control organisation, to ensure efficient investment for continued safe and reliable services.
- Address specific vulnerabilities, based on regular risk assessments and reviews of resilience problems that have occurred in the UK and elsewhere, e.g. companies have been implementing a large programme of flood protection measures over recent years, which is due for completion by the early 2020s.
- Put in place contingency arrangements: Energy companies have worked extensively to put in place contingency plans in the event of disruption due to severe weather-related events and to manage staffing in the event of pandemic flu and other risks.

ii) Building resilience

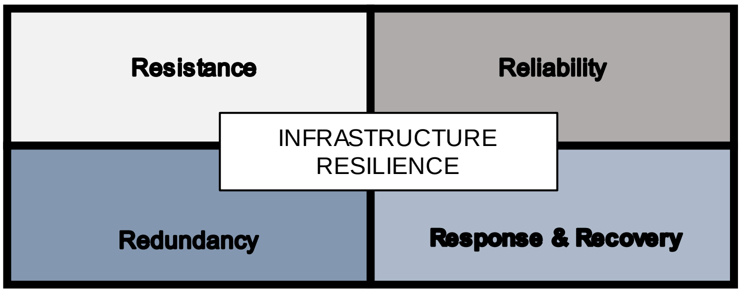
The energy sector is made up of upstream oil and gas, downstream oil and gas and electricity. Although infrastructure types and business environments differ, each sub-sector has invested to build resilience to major risks.

- Electricity: Ensuring an acceptable and affordable level of 'black start' service. 'Black start' is the term given to the restoration plans developed by the National Grid to restore the National Electricity Transmission System in the event of its total failure.
- Energy networks: Assess the risk caused by a cyberattack.
- Downstream oil: Maintain the function to provide fuel supply when a serious disruption occurs.
- Energy sector flood resilience: Continuously assess the risk of floods on energy-related assets and assess the flood protection improvement programmes.

5) Components of infrastructure resilience

The government specifies, as core objectives, the reduction of the vulnerability of critical national infrastructure against threats and hazards as well as the improvement of resilience, by enhancing the durability of critical infrastructure and the capability to restore it from disruption. The approach to resilience consists of four components (Figure 5).

Figure 5: Components of Infrastructure Resilience



Source: Author, based on Cabinet Office (2019).

- Resistance: Concerns direct physical protection (e.g. against floods). Resistance is ensured by preventing damage or disruption through the protection of infrastructure against threats and hazards.
- Reliability: The capability of infrastructure to maintain operations under a range of conditions to mitigate damage from an event.
- Redundancy: The adaptability of an asset or network to ensure the availability of backup infrastructure, systems or processes, or spare capacity (e.g. backup data centres).
- Response and recovery: An organisation's ability to rapidly and effectively respond to, and recover from, disruptive events.

6) Roles and Responsibilities

Various organisations – including owners, operators, emergency services, local authorities and the Cabinet Office – are responsible for the security and resilience of critical sectors. The responsibility of each entity is as follows:

- Infrastructure owners and operators
- ・ Daily operation of the Critical Infrastructure.
- ・ Perform a risk assessment for each asset, and make a calculated decision on the maintenance, training, and investment to improve the security and resilience of each organisation and asset.
- Regulators
- ・ Provide support for lead government departments by implementing related legislation and regulation.
- ・ To build resilience, intervene in and request organisations to satisfy their security and resilience obligations and criteria as a condition to continue operations.

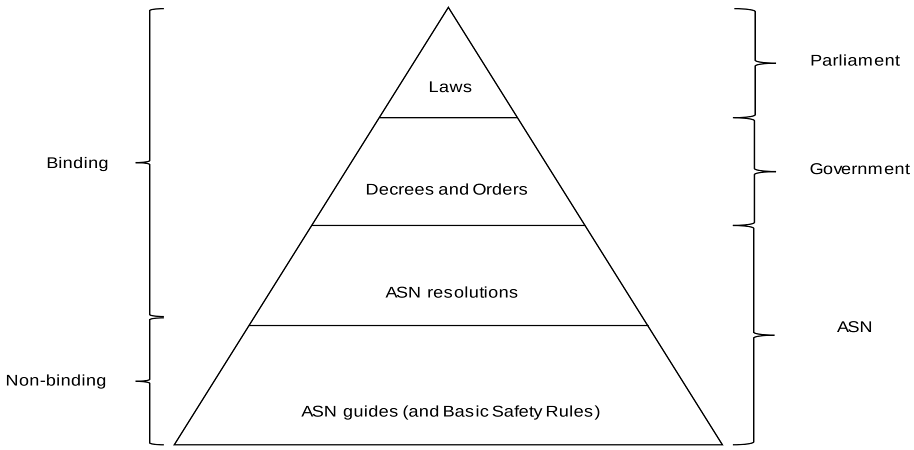
- Local authorities and emergency services
  - In accordance with the Civil Contingencies Act, 2004, identify and assess the possibility and impacts of potential emergencies, such as infrastructure emergencies, for people in the district.
  - Develop an emergency response plan to cope with the above risks.
- Government agencies
  - Provide advice related to the infrastructure risk to the national government, regulators, owners of the infrastructure facility, and operators; and mitigate the risk.
  - Provide integrated advice on physical and human security to reduce risks and mitigate vulnerability against terrorism, espionage activities, and other threats to national security.
- Lead government departments
  - Ensure sector-specific security and implement resilience policies, including legislation.

2.3. Disaster Mitigation and Emergency Preparedness in France

2.3.1. Nuclear safety legal system

France has an organised legal system for nuclear safety (Figure 6). The legal binding force consists of laws enacted by the parliament, ordonnances prescribed for a short term to implement the government's plans, decrees issued by the President or the Prime Minister, orders issued by the ministers, and resolutions enacted by the ASN on nuclear safety and radiation protection. In addition, ASN issues non-binding guides and basic safety rules.

Figure 6: Legal Structure of Nuclear Sector in France



ASN = Autorité de sûreté nucléaire (Nuclear Safety Authority).
Source: Author, based on ASN (2019).

Law. The law on nuclear safety that is applicable to nuclear facilities is ACT No. 2006-686 of 13 June 2006 on Transparency and Security in the Nuclear Field, which prescribes the followings:

- The nuclear safety authority shall be an independent administrative authority.
- The local information committee shall be established in a region in which a nuclear facility is placed; and carry out information provision and discussions for the nuclear safety and radiation protection of the relevant facilities.
- The high committee for transparency and information shall carry out information provision and discussions about the risks and impacts on human health and the environment.

Decrees. The framework of the procedures for basic nuclear installations (BNI) – including their construction, operation, shutdown, decommissioning, and licence termination – are clarified in the BNI procedures decree (Decree 2007-1557 of 2 November 2007 concerning BNI and the supervision of the transport of radioactive materials with respect to nuclear safety) (ASN, 2007). The relationship between the minister responsible for nuclear safety and ASN is also prescribed in this Decree.

Orders. Applicable technical regulations are prescribed in the Order of 7 February 2012 setting the general rules relative to BNI. The order clarifies the requirements that should be applied to BNI from the viewpoint of consideration/safety of the public and natural environmental protection.

The ASN resolutions. It aims at clarifying the contents of the decrees and orders relating to nuclear safety and radiation protection and should be authorised by the responsible minister.

The ASN guides. It has been developed as educational tools for experts.

2.3.2. Disaster Mitigation and Emergency Preparedness

1) Establishment of ASN

Based on the Law on Transparency and Security in the Nuclear Field, the independent administrative authority ASN was established in 2006 to regulate nuclear safety and radiation protection associated with nuclear activities (ASN, 2019). The primary roles are as follows:

- Provide advice on the drafts of decrees and orders prescribed by the government for regulations.
- Make legal decisions to show the measures to implement decrees and orders.
- Examine applications for construction approval and decommissioning, operate them, and modify their approval.
- Provide technical support to the supervisory authority that develops the emergency response plan.
- Provide information to citizens in its authority.
- Monitor the adaptability of public research.

ASN comprises the following entities:

- ASN Commission

- ASN Head Office Department
  - Nuclear Power Generation Office
  - Nuclear Pressure Instrument Bureau
  - Transport/Radiation Source Office
  - Radioactive Waste/Research Facility/Fuel Cycle Facility Office
  - Medical Radiation Administrative Office
  - Environment/Emergency Response Office
  - International Relations Office
  - Public Relations Office
  - General Affairs
  - Information/Technology Administrative Room

- ASN regional divisions
  Eleven regional divisions assist politicians who are responsible for protecting their people and supervising tasks to maintain the safety of the nuclear facilities when an emergency occurs. To prepare for such situations, they participate in the development of the emergency response plan, whose draft is created by politicians and regularly participate in emergency response training. In addition, they contribute to ASN's mandatory of information disclosure.

- Institut de radioprotection et de sûreté nucléaire (Institute for Radiation Protection and Nuclear Safety: IRSN)
  In 2002, the IRSN was established as part of the national reorganisation to consolidate public expertise and research resources in the field of radiation protection regulation. The ASN director general is assigned to the IRSN board of directors and ASN is involved in the strategic plan of IRSN.

- Groupe permanent d'experts (Expert Advisory Committee :GPE)
  The GPE consists of experts from universities, associations, assessment authorities, research institutions, and etc., individually assigned based on their expertise. ASN consults seven GPEs, each of which has its own specialised field, for opinions before it makes any decision. With the goal of improving nuclear safety and radiation protection transparency, ASN publishes the documents relating to the meetings of these GPEs: ASN referral of a particular subject to the GPE, summary of the IRSN report, GPE opinion and ASN stance.

In response to the Fukushima Daiichi NPS Accident in 2011, based on stress tests performed in European countries including France,[4] ASN issued a decision in 2012 to the licensees in France, namely, EDF, the French Alternative Energies and Atomic Energy Commission (CEA), and the Institut Laue–Langevin (ILL), requiring the followings (ASN, 2012):

- Establish a 'hardened safety core' through physical and organisational measures.
- To cope with extreme external events, establish an on-site emergency centre that performs comprehensive emergency supervision of nuclear sites.
- EDF shall establish FARN, which can intervene in nuclear sites in case of accidents or under conditions that can result in accidents.

The ASN decision was also issued to EDF, specifying how the sites were to be prepared for 'hardened safety core' requirements and management structure in the case of an emergency.

EDF was to act following the three phases below:

- First phase (2012–2015): Take temporary measures or measures with movable instruments to enhance the handling of major events that occur when the entire heat removal function is lost, or the entire power is lost.
- Second phase (2015–around 2020): Implement robust and reliable design and organisational measures for extreme events.
- Third phase (2019): Implement supplementary measures for the second phase (Improve the scope of the potential accident scenario, especially for expected accidents)

2) The accident of off-site electricity supply loss at Blayais power plant in 1999 due to a flood

i) Background

The Blayais nuclear power plant is located at Gironde, about 50 kilometres northwest of Bordeaux, and comprises four pressurised water reactors of 900 Megawatt electrical (MWe). To secure water for cooling, it was constructed along the Gironde River. EDF's 1998 annual plant security report stated that the bank needed to be heightened. The construction of the bank was planned to start in 2000, but it was deferred to 2002.

On 27–28 December 1999, a severe storm occurred near the Blayais nuclear power plant. At that time, units 1, 2, and 4 of the plant were operating at 100% power and unit 3 was in a cold shutdown state after fuels were reloaded. The severe storm caused the river mouth water level of the Gironde to rise. In units 1 and 2, the water level exceeded the design basis level (about 5 metres) and several sections were flooded. As a result, safety functions were lost because the pump and the power distribution equipment and the cooling system had stopped. The following safety functions were

[4] A risk and safety assessment was performed on all nuclear power plants in the EU to evaluate the response capacity against severe accidents that are beyond expectation and the tolerability of nuclear power plants against external events such as earthquakes, floods, terrorism, and airplane crashes.

lost:

- Essential service water system pump of unit 1 (a part of the decay heat removal function by the containment vessel spray heat exchanger)
- Electrical system of units 1 and 2 (the flood expanded from the unit 1 electricity building to the unit 2 electricity building through the power line conduit)
- 225 kilovolts of auxiliary electricity supplies in all units (24 hours of outage)
- 400 kilovolt power transmission lines of units 2 and 4 (3 hours of outage)

After the accident, since the steam generator could be used to cool the cores,

- The essential service water system recovered on 30 December.
- Unit 4 restarted on 30th.
- The electricity supply was secured on 30th.
- The emergency was cleared on 30th (Gorbatchev et al., 2001).

As for countermeasures, EDF decided to adopt the following:

- Flooding hazard
- Identify all events in all 19 power plants, which could lead to a flood.
- Reassess the impact of the flooding hazard.
- Protective measures
- Identify the equipment that should be protected.
- Review the protective measures relating to the structure, equipment, procedure and organisation.
- Implement refinements and improvements as required.
- Develop the support function of the power station and the procedure manual in case of flooding.
- Develop the procedure manual in case of flooding as required.
- Analyse the risks regarding access to the site, loss of off-site electricity supply, the heat sinks and communication.
- Build measures to avert or handle the risks.

ii) Lessons learned

The following lessons were learned from the accident at Blayais power plant caused by a flood, in which the off-site electricity supply was lost:

- Reassess the design rules relating to external overflow streams and leverage the lessons learned to improve the protection of NPPs.
- Conduct comprehensive reviews in various sectors – including research and development, engineering and operations (in the Blayais case, this was carried out for 7 years after the accident).
- Enhance the protection measures against flooding and implement flood measures specific to each site.
- Periodically judge the necessity of additional measures by conducting surveys of meteorological phenomena.

The accident at Blayais nuclear power station led serious consideration of external events after the accident in France. On the other hand, for the accident at the Blayais nuclear power station, investigations and analyses had been done but not enough measures had been implemented (Yamaguchi, 2012).

2.3.3. Response

1) RFS 1.2.e – Guidelines for flood protection for pressurised water reactors

In response to the severe storm that hit Gironde in December 1999 and partial water intrusion of the Blayais nuclear power station, nuclear operators (EDF as well as ASN and IRSN) conducted a reassessment from a wide scope of flood protection procedures for nuclear power stations. This reassessment revealed inadequacies in "RFS 1.2.e du 12/04/1984" (ASN, 1984), which prescribes the guidelines for flood protection for pressurised water reactors.

In response to the tsunami that hit Japan on 11 March 2011 and the enormous impact of the Fukushima Daiichi NPS Accident, at the request of ASN, IRSN submitted a draft standards guide on flood protection on 24 May 2012 for nuclear operators to the reactor experts standing group (GPR) and the research centre and plant experts standing group (GPU).

To define and identify the type of floods that would be candidates for the protection of nuclear facilities and to show all the recommendations on protection measures to be implemented, ASN Guide No. 13 (outside flood protection of the BNI) (ASN, 2013) was developed to replace the RFS based on the proposals of the working group, which comprised representatives from ASN, IRSN, nuclear operators and experts in hydrologic, hydraulics and meteorology.

2) ASN Guide No. 13: Protection of Basic Nuclear Installations against External Flooding

On 8 January 2013, the final version of ASN Guide No. 13 was authorised by the ASN committee and became the new guide – overriding RFS 1.2.e.

ASN Guide No. 13 for operators can be used to assess and quantify the external flood risks of the facility and detail recommendations for protection measures to handle the risks.

This guide was developed based on a set of lessons learned from the partial water intrusion of the Blayais nuclear power station caused by the severe storm in December 1999. In response to this event, under the supervision of ASN, EDF reassessed the safety of facilities against flood risks and adopted safety improvement plans.

In parallel with the improvement plans for existing facilities at the time, ASN launched a working group aimed at conducting fundamental discussions on outside flood risks from the beginning of the design, and establishing regulations applied to all new BNI from 2005.

ASN Guide No. 13, which is applied to new and existing BNI, has been implemented mainly in the following four phases through a coordination process amongst interested parties for 8 years:

- Launching the working group. The working group was jointly operated by ASN and IRSN and consisted of the representatives of experts from specialised hydrologic, hydraulics and meteorology institutions as well as operators. The working group was launched in 2005 and submitted the first draft guide in December 2009.
- Public hearing. The public hearing on the draft guide, held from 15 June to 15 September 2010. Public hearing provided more than 350 suggestions for improvement.
- Opinion exchange meeting. Held between IRSN and operators from February to October 2011 to form a consensus through detailed consideration of the improvement plan for the guide.
- Opinion brief of experts standing group. On 24 May 2012, the GPR and GPU submitted an opinion brief about the issues for which reservation conditions were set.

3) Nuclear Rapid Action Force (FARN)

After Fukushima Daiichi NPS Accident, to enhance the crisis response capacity on a voluntary basis, EDF established FARN as the organisation to provide human resources and response crisis support in 2011. FARN has a head office in Paris and four local head offices in Civaux, Dampierre, Paluel and Bugey. Its purpose is to provide reinforcing human resources and emergency instruments within 24 hours of an emergency in any of the 58 nuclear power plants at 19 sites in France. It was established as a voluntary measure in 2011 but was reorganised according to additional requirements of ASN since it was incorporated in the requirements of the regulator (ASN) in 2012.

The FARN rules specify the response when emergency situations occur as follows:

- Gather at the head office within 1 hour after occurrence.
- Leave for the site within 2 hours.
- Dispatch special teams and carry all equipment into the power station within 12 hours.
- Prepare for operational start within 24 hours.

FARN assumes any kinds of emergency situations.

In the case of an emergency response to severe accidents, the insight of people with military experience is indispensable since the situation is confused by a variety of information and so swift and flexible responses are required. Hence, persons with military experience are assigned as the managers of two of the four head offices. EDF Site superintendents are assigned to the manager of the other two head offices. Each local head office consists of five teams and each team has 14 members. Each member of a FARN team works in various departments, of the power station under normal conditions and 6 months are used for training in a team.

4) ASN's order to shutdown Tricastin power station

After Fukushima Daiichi NPS Accident, ASN directed EDF to adopt several durability enhancement measures so that the nuclear power stations would be safe even if a severe accident occurred. It also requested each site to secure the hard core[5] (robust equipment which was the core of safety) to be able to cope with a severe accident when it occurred.

Regarding the risk of severe floods, in June 2012 ASN requested the licence holders of the Tricastin nuclear power station to investigate and assess the following items within 1 year:

- The seismic resistance level of the bank and other constructions that protect the facility from floods.
- The impact of damage when the bank or other constructions are destroyed.
- Technological measures to maintain the protection of hardened core equipment and instruments.
- Characteristics of materials, a variety of structures, elements leading to degradation of the bank, and the mechanism of degradation.
- The stability of the water safety gate when the water level of the canal is significantly lowered because the left bank of the Donzère-Mondragona canal is breached.

In December 2012, former Areva SA[6] submitted to ANS the latest flood risk assessment for the nuclear fuel cycle facility at the Tricastin site.

Tricastin site is a large complex of nuclear facilities involving nuclear fuel cycle facilities of former AREVA SA and four reactors of EDF. The four reactors at the Tricastin nuclear power station are pressurised water reactors – they have 3.6 million kW of power generation capacity in total and generate about 6% of the total power generation in France. Units 1 and 2 started operations in 1980 and units 3 and 4 started operations in 1981, so they are near the end of lifetime. In addition, ASN approved continuing operation of reactor 1 at the Tricastin NPP for an additional ten years after thirty years in service in December 2010 (ASN, 2010). The Tricastin nuclear power station is located near the west bank of the Donzère-Mondragona canal near the Rhone River, and water is taken from the canal for cooling.

In 2013, EDF submitted the first assessment, which highlighted the need for engineering geology investigations and a seismic resistance assessment based on the investigation results for several parts of the bank. After implementing many assessments, ASN concluded that some parts of the bank were not durable to earthquakes, the result was reported to ASN in August 2017 (ASN, 2017). Former Areva SA also informed ASN in August 2017 that some parts of the nuclear fuel cycle facilities

[5] The concept of 'hardened core' was defined by ASN on 26 June 2012 based on the results of the stress test after Fukushima Daiichi NPS Accident.
[6] Areva SA changed its name to Framatome (Plants) and to ORANO (Fuel services) in 2018.

at the Tricastin site were not durable to earthquakes. ASN noted the risk of a severe accident such as Fukushima Daiichi NPS Accident if the water intruded into the reactor facility from the canal as the result of an earthquake or severe storm. ASN classified this event International Nuclear and Radiological Event Scale (INES Level 2) (EDF, 2017).

Based on the above, in September 2017, ASN ordered the Tricastin nuclear power station to shut down all four of its reactors.

Tricastin case study indicates that the French regulator (ASN) is applying stricter criteria than ever to the resilience of nuclear facilities to natural disasters. It prepares for natural disasters that have a low probability of occurring since it is too late to prepare after an accident has occurred. This serves as an important reference for Asian countries, which are likely to face more severe natural disasters than Europe.

EDF strengthened the embankment after obtaining details of its composition through geotechnical surveys. The assessment carried out by IRSN at the request of ASN on the strengthened embankment confirms that there would be no failure in the event of a safe shutdown earthquake – the largest earthquake studied in nuclear safety. However, it revealed that risks of localised landslides existed in certain conditions if the stability of the embankment was compromised. This would require repairs to be carried out. Therefore, EDF has pre-positioned equipment near the embankment to implement the necessary repair works on landslides following an earthquake.

In addition, regarding the Comurhex 1 uranium conversion facility which is a part of nuclear fuel cycle facilities in Tricastin site, ASN authorised its restart on 23 October 2017 following steps taken to reinforce measures controlling the release of chemicals if the embankment were to fail after an earthquake (ASN, 2017).

The case study of Tricastin indicates that the French regulator (ASN) is applying stricter criteria than ever to the resilience of nuclear facilities to natural disasters. It prepares for natural disasters that have a low probability of occurring since it is too late to prepare after an accident has occurred. This serves as an important reference for Asian countries, which are likely to face more severe natural disasters than Europe.

2-4. Disaster Mitigation and Emergency Preparedness in Japan

2-4-1. Ministerial Meeting on Emergency Inspection of Critical Infrastructure

In 2018, Japan experienced a major blackout and large-scale damage to its electricity infrastructure supply due to a series of disasters including heavy rains, typhoons and the Hokkaido Eastern Iburi earthquake. These disasters revealed several issues, including how to transmit information and cooperate over wide areas in the power industry, and promoted recognition of the importance of stable supplies in the electricity policy.

Japanese government started to discuss how to maintain critical infrastructure to be operational even after a severe disaster. Discussions were implemented from viewpoints of people's lives and economic activities. In September 2018, the Ministerial Meeting on Emergency Inspection of Critical Infrastructure (Cabinet Secretariat, 2018a) decided to conduct inspections related to 132 issues regarding the electric and other infrastructure and put together the measures and policies of the government. The main points of the Prime Minister's statement in the Ministerial Meeting on Emergency Inspection of Critical Infrastructure is:

- Conduct urgent inspections of Critical Infrastructure (e.g. electricity and airports) throughout the country to ensure they maintain their functionality in all kinds of disasters and put together countermeasures by the end of November 2018.
- Each minister must develop countermeasures to strengthen Critical Infrastructure under the supervision of the Minister in charge of Building National Resilience, Mr. Hachiro Okonogi.
- A comprehensive emergency countermeasures to respond to significant changes in the weather (e.g. concentrated heavy rains over a wide area) will be undertaken in 3 years for disaster prevention, disaster mitigation, and national resilience and building a safe and resilient Japan.

The countermeasures to be addressed in the emergency inspection of critical infrastructure are as follows:

- Functional maintenance of Critical Infrastructure for disaster prevention
- ・ Large-scale water intrusion, landslides, volcanic eruptions, etc.
- ・ Large-scale earthquakes, tsunami, etc.
- ・ Basic facilities, etc., required for disaster response
- ・ Rescue, emergency, medical activities, etc.
- ・ Information required for evacuation activities

- Functional maintenance of Critical Infrastructure that supports the national economy and livelihood of Japanese people.
- ・ Food supply, lifeline such as electricity, gas and water, supply chain, etc.
- ・ Land, air, and sea transportation infrastructure
- ・ Information and communication technology infrastructure and information services

2.4.2. Investigation Committee on the Major Blackout by the 2018 Hokkaido Eastern Iburi Earthquake

Overview of the Major Blackout by the 2018 Hokkaido Eastern Iburi Earthquake as follows;

1) From 3:08 to 3:09 am on 6th September 2018

- Units2 and 4 of the Tomato–Atsuma thermal power plant shutdown due to the earthquake triggered power system frequency drop.
- Load rejected by starting operation of under frequency relay (UFR), which caused oversupply of electric power in eastern Hokkaido.
- Eastern Hokkaido was isolated and became single transmission system by transmission accidents, which increased frequency in eastern Hokkaido.
- Increasing frequency in eastern Hokkaido led to shutdown of hydropower plan.
- Frequency in eastern Hokkaido decreased by shutdown of hydropower plan, which triggered temporary blackout in eastern Hokkaido.

2) From 3:09 to 3:19 am on 6th September 2018

- After stabilizing of frequency, frequency gradually dropped by increasing of electricity demands.
- Load dispatching centre ordered for thermal power plants to rise output. Frequency turned to be recovering.

3) From 3:20 to 3:24 am on 6th September 2018

- Output of unit 1 of the Tomato–Atsuma thermal power plant fluctuated and gradually decreased.
- As a result of output decrease, frequency dropped and load rejected.

4) From 3:24 to 3:25 am on 6th September 2018

- As unit 1 of the Tomato–Atsuma thermal power plant shut down, frequency dropped again.
- Frequency drop caused shutdown of other thermal power plants and hydropower plants for equipment protection.
- Kita-Hon Interconnection System became out of service.
- As a result of the above events, power supply was lost and finally blackout occurred.

On 11 September 2018, the Minister of Economy, Trade and Industry directed Hokkaido Electric Power and the Organization for Cross-regional Coordination of Transmission Operators (OCCTO) to begin investigations on the major blackout and submit an intermediate report in mid-October.

The OCCTO launched the Investigation Committee on the Major Blackout Caused by the 2018 Hokkaido Eastern Iburi Earthquake (Organization for Cross-regional Coordination of Transmission Operation, 2018)to conduct a transparent and fair investigation, in collaboration with impartial third parties. The structure of the investigation was as follows:

- Analysis of the causes that triggered major blackouts across Hokkaido.
- Technical verification of the process to secure supply capacity of about 3 million kW after a major blackout.
- Examination of measures for the prevention of recurrence, which should be undertaken in the Hokkaido area, etc.

The investigation committee submitted an intermediate report to the minister of economy, trade and industry on 25 October 2018. The contents were as follows:

- Sequence of events from the occurrence of the earthquake to the blackout.
- A combination of factors was involved in causing the blackout, one of which was the shutdown of units 1, 2 and 4 of the Tomato–Atsuma thermal power plant and the other was the accidents involving four power lines, which triggered the shutdown of hydropower stations.
- The margin in the interconnection facility was used to restore the frequency, but the blackout was triggered when unit 1 of the Tomato–Atsuma thermal power plant tripped, and the frequency recovery failed since the maximum amount of receiving power had been exceeded.

- Sequence of events from the blackout to ensure supply capacity of about 3 million kW.
  - 45 hours were required from the blackout to the resumption of supply to all areas since problems occurred due to abnormal current flows after transmission to major transformers was resumed.
  - Recovery time for at least several hours was necessary to secure safety even if no technical problem was found.
- Short-term recurrence prevention measures (winter 2018/2019).
  - Start three units of Tomato–Atsuma thermal power plant (units 1, 2, and 4) based on the operation of Kyogoku power station (hydropower).
  - Suppress the output of unit 1 of Tomato–Atsuma thermal power plant or secure alternative backup power, when the Kyogoku power station (hydropower) is shut down.
  - Take additional measures and perform monitoring through OCCTO when the Kyogoku power station (hydropower) is shut down.
  - Increase the demand ratio of the electricity supply that is continuously operational even when the frequency rate decreases.

The final report was submitted on 19 December 2018 (Organization for Cross-regional Coordination of Transmission Operation, 2018). The contents added to the intermediate report are as follows:

- Medium- and long-term operational measures.
  - In the future, medium- and long-term operational measures must be reviewed periodically according to changes in the power system configuration and the balance of supply and demand. A simulation assuming an unplanned shutdown of one of the Tomari nuclear units would be necessary when their restart date is determined.
- Medium- and long-term measures for facility operation.
  - The government must examine cost allocation when enhancement is required.
  - OCCTO must consider additional enhancement and specific method conversions for the Hokkaido–Honshu High Voltage Direct Current (HVDC) interconnection.
  - Based on the national policy, the government and OCCTO must specify what routes should be taken and how much capacity should be additionally built by spring 2019, after the effectiveness of such measures is verified by a simulation.

2.4.3. Working Group on Electricity Resilience

To examine the issues and measures for building highly resilient electric infrastructure/systems, the Ministry of Economy, Trade and Industry launched the joint Working Group on Electricity Resilience (Ministry of Economy, Trade and Industry, 2018) – under the Advisory Committee on Natural Resources, Electricity/Gas Business Subcommittee, Electricity/Gas Basic Policy Subcommittee, Industrial Structure Council, Product Security Subcommittee for Preservation/Consumer Life, and Subcommittee on Electric Power Safety. The background of this working group is as follows:

- In 2018, Japan experienced major blackout and large-scale damage to the electricity supply due to a series of disasters such as the Hokkaido Eastern Iburi earthquake. These disasters revealed several issues, including how to transmit information and cooperate over wide areas in the power industry, and clarified the importance of a stable electricity supply and the need to examine how to develop highly resilient electricity infrastructure/systems.
- In consideration of the impacts of a series of recent disasters on people's life and economic activities, the Ministerial Meeting on Emergency Inspection of Critical Infrastructure held on 21 September 2018 decided to conduct urgent inspections of critical infrastructure so that they could maintain their functionality, and proposed related measures and policies for the government. OCCTO also verified the causes of major blackouts and the recurrence prevention measures and submitted an intermediate report.
- The Working Group on Electricity Resilience (METI, 2018b) was to take into consideration of the responses of the government to a series of disasters based on the verification and evaluation of the major blackout in Hokkaido. The Working Group on Electricity Resilience was to conduct emergency inspection of Critical Infrastructure and propose a package of measures.

An intermediate report was issued on 28 November 2018. The relevant contents of the emergency inspection of Critical Infrastructure and the package of measures are as follows:

- Emergency inspection of Critical Infrastructure.
  - The emergency inspection of critical infrastructure (gas and fuel) confirmed that no blackouts would occur in eastern or western Japan under certain conditions.
  - Regarding electricity infrastructure, since the operational reviews have been conducted and verified for the scenario in which all units of the Tomato–Atsuma thermal power plant are shut down and measures have been implemented, it was evaluated that no blackout would occur in the Hokkaido area. Since there are high-power interconnection lines between areas in east and west Japan, the impact of a local shutdown is relatively small, and no blackout would occur in these areas. It was also evaluated that no blackout would occur in the Okinawa area provided that certain operational measures are implemented.

Table 3: Results and Measures of Critical Infrastructure Priority Actions (Electricity)

Sector	Infrastructure	Item	Summary of priority action
Energy -Electricity	Power generation facilities/Power grids	Critical infrastructure priority action	Implement the following measures to secure more resilience. ⅰ. preventive measures for large-scale blackout ⅱ. Disaster prevention such as infrastructure reinforcement ⅲ. Cooperation with utilities (Early recovery) ⅳ. Reinforcement of information transmission ⅴ. Mitigation measures against impacts of blackout

Source: Excerpt from the intermediate summary of the working group on electricity resilience (METI, 2018b), 27 November 2018.
https://www.kantei.go.jp/jp/singi/jyuyouinfura/index.html (accessed 20 Dec 2019) (in Japanese).

- Measures to prevent blackouts for the future
  - Take all possible measures to prevent blackouts from occurring in Hokkaido and take measures to ensure the resilience of the infrastructure throughout the country, promote cooperation with operators for early recovery, and reinforce the transmission of information.
  - Since the resilience measure package is required to produce effects swiftly regarding disasters that are expected to occur, it comprises two types of actions: (i) priority actions, which are conducted swiftly after being arranged, and (ii) medium-term actions, which contain systemic reforms. Measures are roughly classified into two types: (a) disaster prevention actions to prevent the occurrence of blackouts as much as possible; and (b) disaster mitigation actions to minimise the damage and risks at the time of outages, including cooperation with utility operators for early recovery and reinforcement of prompt and accurate information dissemination.

Table 4: Policy Packages for Achieving Goals (Electricity)

Items	Mid-term/ Priority action	Actions
Minimise damage to property of the citizenry and public facilities	Mid-term action	• Consideration of regional cooperation without Hokkaido • Consideration of systems which secure power supply • Building a regular confirmation process about likelihood of risks of blackout • Promotion of disaster-resistant renewable energy • Consideration of clear stipulation
Achieve swift recovery and reconstruction	Priority action	• Speed-up actions for recovery by supports of other electricity companies • Facilitation of recovery works connecting with relative authorities and local governments
	Mid-term action	• Specification standardization of power grid facilities • Establishment of systems which are able to remove fallen trees swiftly • Consideration of cost recovery system for disaster measures
Risk communication	Priority action	• Information transmission on the same level as public using multiple channels such as Twitter, radio, etc • Accelerated recovery after disaster situation by development of systems
	Mid-term action	• Collection of information using state-of- the-art technologies such as drones, estimate system of disasters, etc

Source: Author, referenced from the intermediate summary of the working group on electricity resilience (MEI, 2018b), 27 November 2018.
https://www.kantei.go.jp/jp/singi/jyuyouinfura/index.html (accessed 20 December 2019) (in Japanese).

2.4.4. Three-year Emergency Response Plan for Disaster Prevention, Disaster Mitigation, and Building National Resilience

Based on the Ministerial Meeting on Emergency Inspection of Critical Infrastructure on 14 December 2018, the Three-year Emergency Response Plan for Disaster Prevention, Disaster Mitigation, and Building National Resilience (Cabinet Secretariat, 2018b) was approved in a ministerial meeting. Based on the inspection results according to the Ministerial Meeting on Emergency Inspection of Critical Infrastructure, the Three-year Emergency Response Plan for Disaster Prevention was decided to maintain the functionality of critical infrastructure. 20 programs out of 45 programs of the Fundamental Plan for National Resilience were chosen as priority actions. Both hard and soft measures will be implemented for 3 years from 2018 to 2020 to support the national economy and social life. Some 160 items are listed as emergency measures. The total cost of the whole project is planned to be about ¥7 trillion. In addition to the fiscal measures, ¥0.6 trillion will be allocated through financial investments and loans, and the private sector is expected to bear ¥0.4 trillion of the cost. ¥0.3 trillion was allocated in the second supplementary budget of 2018. For the other actions, the initial budget of 2019 and the temporary measures and special measures of 2020 are planned to be used.

Table 5: Contents of the Measures and Project Size

Measures	Cost
I. Functional maintenance of critical infrastructures for disaster prevention	About 3.5 trillion ¥
(1) Prevent/minimize large-scale water intrusion, landslide disasters, and damage due to earthquakes, tsunami, etc	About 2.8 trillion ¥
(2) Secure the response capabilities for disasters such as rescue, emergency, medical activities, etc	About 0.5 trillion ¥
(3) Secure the information required for evacuation activities	About 0.2 trillion ¥
II. Functional maintenance of critical infrastructures that support national economy and social life	About 3.5 trillion ¥
(1) Secure the energy supply such as electricity, etc (2) Secure the food supply, lifeline, supply chain, etc	About 0.3 trillion ¥ About 1.1 trillion ¥
(3) Secure the transportation network of land, air, and sea	About 2.0 trillion ¥
(4) Secure the information communication function/information services necessary for daily life	About 0.02 trillion ¥

Source: Author, referenced from Three-year Emergency Response Plan for Disaster Prevention, Disaster Mitigation, and Building National Resilience 14 December 2018. https://www.kantei.go.jp/jp/singi/jyuyouinfura/sankanen/siryou1.pdf (Accessed 20 December 2019) (in Japanese).

For the functional maintenance of Critical Infrastructure that supports the national economy and society, the project size is planned to be ¥0.3 trillion and the following measures will be implemented:

- To introduce about 550,000 kW of decentralised power generation to strengthen the energy demand–supply structure.
- To maintain, at the time of a disaster, the equivalent level of fuel shipment capabilities during ordinary times in each region, implement and reinforce the emergency power generating equipment at oil terminals that have no emergency power generating equipment and refineries/oil terminals, which are the keystone of fuel supplies.
- To ensure an adequate fuel supply system for fuel demand during blackouts, place service stations equipped with a private power generation facility at 8,000 points across the country. To cope with the fuel supply demand at the time of blackout, deploy 6,700 tank lorries for emergency deliveries to secure the system for flexible response.

2.4.5. Response

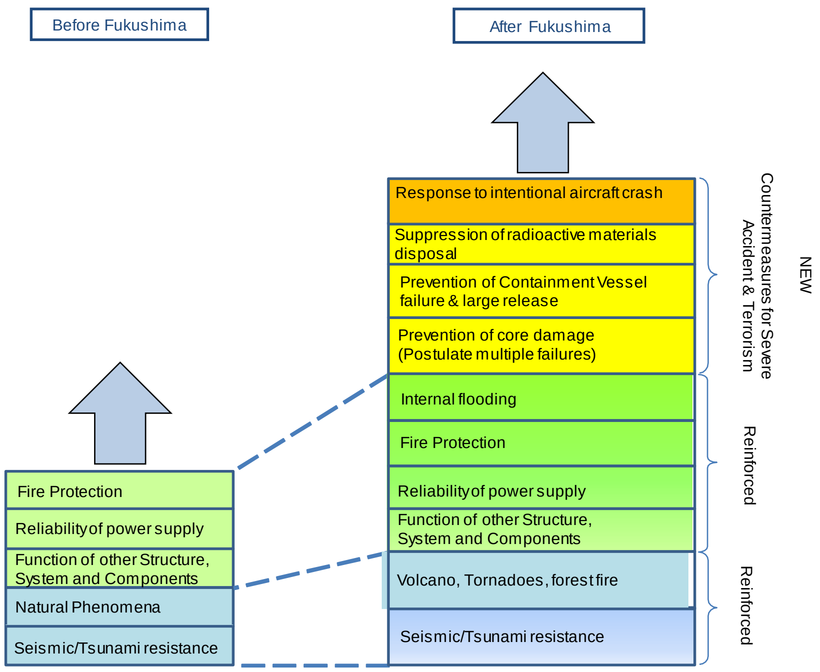
1) New regulatory requirements for commercial nuclear power plants

Before Fukushima Daiichi NPS Accident, the highest level of safety was not guaranteed since "beyond-design-basis-accidents (BDBA)", which frequency was extremely low, were not included as a regulatory requirement. The measures against BDBA were not satisfactory, and no legal mechanism was prepared to apply new safety requirement retroactively to existing nuclear power stations (Backfit Rule). In addition, no comprehensive assessment had been conducted to include external events such as fires, volcanic eruptions, and landslides, which could cause accidents.

In response to the above, safety requirement by NRA was amended in June 2012 based on lessons learned from Fukushima Daiichi NPS Accident, prescribing the inclusion of BDBA measures, and a backfit was applied to the safety measures. Application of the new regulatory requirements was started in July 2013. The new regulatory requirements were based on Defence in Depth[7], from the viewpoint of preventing a loss of the safety function.

The new safety requirement significantly raised the assumption level of natural disasters and reinforced the measures for events such as fires, which could result in a loss of the safety functions through common factors in addition to natural disasters.

Figure 7: Comparison of Safety Requirements



Source: Author, referenced from Nuclear Regulation Authority (n.d.), Regulatory Requirements. https://www.nsr.go.jp/english/regulatory/index.html (accessed 20 December 2019).

[7] Defence in Depth is an approach to designing and operating nuclear facilities that prevent and mitigate accidents that release radiation or hazardous materials. The key is creating multiple independent and redundant layers of defence to compensate for potential human and mechanical failures so that no single layer, no matter how robust, is exclusively relied upon. Defence in Depth includes the use of access controls, physical barriers, redundant and diverse key safety functions, and emergency response measures.

2) Nuclear Safety Reform Plan of Tokyo Electric Power Company

After Fukushima Daiichi NPS Accident, Tokyo Electric Power Company (TEPCO) announced its Reassessment of the Fukushima Daiichi NPS Accident and Nuclear Safety Reform Plan (TEPCO, 2019) in March 2013 and quarterly updates on the progress of these reforms. To strengthen governance, TEPCO developed the Nuclear Power Division Management Model in June 2017 (TEPCO, 2017), which stated the main values of the management model as (i) safety awareness, (ii) the ability to promote dialogue, and (iii) technological capability.

TEPCO redefined its vision and mission as follows:

- Vision: Keep the Fukushima Daiichi NPS Accident firmly in mind; we should be safer today than we were yesterday, and safer tomorrow than today; we call for nuclear power plant operators that keep creating unparalleled safety.
- Mission: To achieve nuclear power generation with safety and efficiency equivalent to the highest international standards.
- Values: Safety awareness, ability to promote dialogue, technological capability.
- Basic policy to achieve goals: Constant reforms and improvements; promotion of work under direct management by seeing, hearing, and feeling.

i) Safety awareness

TEPCO declared "11 March" as the day of reflection for the Fukushima Daiichi NPS Accident to study and discuss the accident each year. 3,000 employees have participated in the reflection day activities since 2012. Other efforts are as follows:

- Independent oversight and monitoring.
- Enhancement of management observation.
- Dialogue with cooperating companies.
- Safety proposal competition.

ii) The ability to promote dialogue

TEPCO assigned 20 risk communicators to inform the media of the situation at NPPs in a timely manner. It also sends direct messages to people through its Homepage, Social Network Service and call centres. Other efforts are as follows:

- Set up a communication booth at wider areas.
- Communicate with local residents.
- Visit all houses located in NPP municipalities once a year.
- Encourage employees to participate in regional events.

iii) Technological capability

TEPCO selected and evaluated 44 natural hazards from multiple sources, including the NRC and The American Society of Mechanical Engineers, and narrowed them down to 11 natural highly probable natural hazards – earthquakes, tsunamis, tornadoes, volcanos, high winds, extreme low temperatures, heavy rain, snow cover, lighting strikes, landslides and biological events. Based on the lessons learned from the Fukushima Daiichi NPS Accident, safety upgrades – such as tide wall/watertight door/drainage systems for tsunamis, prevention of flying objects during tornadoes and measures to combat volcano ash – were implemented at Kashiwazaki–Kariwa NPP.

2.5. Hearing Survey

In this section, the outputs of the hearing survey are addressed. Most of the information has disclosed sources, however, some information was provided from informers verbally.

2.5.1. US

In the US, resilience is defined as the capability to enable an early recovery after natural disasters and have a backup system to cover existing systems when a failure is detected. After the Three Mile Island accident in 1979[8], several institutes including the US nuclear power operators and plant vendors established the Institute of Nuclear Power Operations (INPO) to promote the highest level of safety and reliability (excellence) for the operation of commercial nuclear power stations. Memoranda of understanding were concluded between INPO and the NRC regarding the participation of INPO in the operational data, inspections/assessments, trainings, and NRC accident investigation teams. INPO has a complementary relationship with the NRC – they exchange information on activities during annual meetings or through unofficial communication channels such as e-mail. In the 1980s, the NRC established an on-site emergency response presence that comprised a number of teams. Based on the experience of the simultaneous multiple terrorist attacks, damage caused by hurricanes, and Fukushima Daiichi NPS Accident, it promoted the development of integrated and comprehensive emergency assessment, which was conducted separately up to that point. NRC emergency response activities include dispatching staff to power plants, providing support to power plant workers to prepare for evacuations, and performing weekly monitoring. The NRC has a relationship with FEMA, which issued the interim Standard Operating Guide (SOG) in August 2018 (FEMA, 2018a). The primary contents are as follows:

1) Background

In 2018, FEMA outlined the vision for emergency management in its Strategic Plan, 2018–2022 (FEMA, 2018b). The vision was based on a path forward to unify and professionalise emergency management across the country. The strategic plan sets out three overarching strategic goals for the organisation:

[8] Three Mile Island Nuclear Accident is an accident occurred at Three Mile Island site, Unit 2 nuclear power plant 10 miles (16 km) southeast of Harrisburg, Pennsylvania. Failure of the cooling system of the Unit 2 nuclear reactor led to overheating and partial melting of the pressurized-water reactor's uranium core and release of radioactive gas and contaminated water. The accident had a number of primary causes, related both to technical malfunction in the condensation system and human error. Three days after the accident, the official issued an advisory to evacuate pregnant women and preschool children living within a 5-mile radius of Three Mile Island, raising fears an explosion and dispersal of radioactivity among residences. The accident increased public concern over the dangers of nuclear power and slowed construction of other reactors in the US.

- Building a culture of preparedness.
- Readying the nation for catastrophic disasters.
- Reducing the complexity of FEMA.

The DHS/FEMA Radiological Emergency Preparedness (REP) Program has the primary responsibility to continually assess the status of off-site emergency preparedness (FEMA, 2019). The REP Program coordinates the National effort to provide state, local and tribal governments with relevant and executable planning, training, exercise guidance and policies necessary to ensure that adequate capabilities exist to prevent, protect against, mitigate the effects of, respond to, and recover from incidents involving commercial NPPs.

FEMA implements the SOG consistent with the agreements in the memorandum of understanding between FEMA and the NRC regarding radiological response, planning and preparedness dated 7 December 2015 (DHS, FEMA and NRC, 2015). If a disaster causes damage or changes to the off-site emergency response infrastructure in the vicinity of NRC-licenced nuclear power plants to the extent that the damage raises serious questions about the continued adequacy of off-site emergency preparedness, the identifying agency – the FEMA REP Program or the NRC – will inform the other promptly. All agency decisions made pursuant to the SOG involving the FEMA REP Program and the NRC, are coordinated at the headquarters level.

2) Purpose

This SOG contains guidelines and procedures for the FEMA REP Program to conduct and document a FEMA-led Preliminary Capabilities Assessment (PCA) and Disaster Initiated Review (DIR).

FEMA Regional Leadership may elect to use this SOG as guidance to evaluate proposed state compensatory measures for unusual situations, such as local, state, or tribal government-driven budget shutdowns. For these instances, the FEMA Region will negotiate the terms of review with the affected state.

Regarding cooperation between the NRC and operators, an effort is made to promote information sharing not only between upper management of the NRC and operators but also between every class of both organisations. Ensuring transparency is one of the core values of the NRC regarding communication between the NRC and local people. In addition to monthly emergency response meetings, a long-term relationship of trust has been built through actions as well as words. Since Fukushima Daiichi NPS Accident, the NRC has been making further efforts, such as offering information on a timely basis to build a steady relationship of trust.

The NRC is an independent organisation whose various sections work independently of each other, so the chair of the NRC may express a dissenting view on statements discussed in the NRC and agreed by a majority. The US is different from Japan in several ways, e.g. a citizen has the right to express his/her opinion directly to the federal government and the President has the right to remove the chair of the NRC.

In the US, the discussion on electricity resilience against natural disasters started in

2017 and a new rule was announced in 2018. In the new rule, in addition to the traditional fuel stock of 90 days, the characteristics of each region and extended targets are added as an index in a realistic perspective. In particular, the reliability standard conventionally only specified that the required amount of the whole system should be functioning, but the new rule incorporated concrete contents such that the power generation and the transmission/distribution grid in a specific region were functioning with no problems, even when hit by natural disasters. In the US, since each state has the right to determine its power generation mix, resilience efforts vary depending on each state government. Hence, neither the federal government nor the DOE has the right to determine the selection of power generation. It is the main role of FERC to verify if the electricity supply selection by each state government is reasonable in the context of the market rule. FERC has recently decided to ensure fuel security during the winter for the state of New England for 2 years from 2024 to 2025 (Ciampoli, 2018; ISO New England, 2018).

Public comments were requested concerning the new rules of resilience, and more than 200 comments have been received, which are under examination. A positive cost–benefit relationship is crucial to the acceptance of new rules in the US. The key is not to seek 100% safety but to examine if the safety secured is worth the cost. If it is determined that it is possible to improve safety without imposing additional regulations, such regulations are judged to be unnecessary. This concept is shared by the people as well as the regulator and industry in the US.

2.5.2. UK

The definition of resilience in the UK is characterised by the examination of two points: (i) early recovery from natural disasters and (ii) preparing measures for potential natural disasters expected to occur 20 or 30 years later. In addition to the measures for the near future, a long-term viewpoint is incorporated, since the Netherlands and several other areas in Europe are located below sea level and the expected sea level rise due to climate change is an imminent issue, although the UK has fewer natural disasters than other areas. International discussions have been held on the technical aspects of resilience, but since it is an issue related to the energy security or energy mix of each country, it is difficult to hold an international discussion from a political viewpoint.

Electricity resilience has been discussed comprehensively since the 2009 flu pandemic. The UK is characterised by the scientific adviser system established by the government, and the chief scientific advisers assigned for each ministry when a serious disaster occurs. When a domestic or international disaster occurs and scientific knowledge is required, the Prime Minister convenes the Cabinet Office Briefing Rooms (COBR). When the COBR asks the chief scientific adviser for advice, they gather related scientists and experts to launch an urgent Scientific Advisory Group for Emergencies (SAGE) and conduct information collection and analysis to develop a response policy (Government of the UK, n.d.).

Nuclear resilience has been discussed comprehensively since Fukushima Daiichi NPS Accident. A SAGE was convened at the time of Fukushima Daiichi NPS Accident to evaluate the impact of the accident and offer advice to the UK government and the British Embassy in Japan with regard to actions that should be taken by the British Embassy in Japan and British citizens.

Since the UK has majorly used Magnox reactors[9] in addition to light-water reactors until 2015, resilience discussion in the UK differs from that of the US. The UK needs resilience discussions regarding Magnox reactors in addition to that of light-water reactors.

The safety authority, ONR, considers NPPs from the technical viewpoint including their types and verifies its soundness against natural disasters. From the economic viewpoint, the cost of nuclear power generation includes the cost of safety measures, but renewable energy generation does not include this cost. Renewable energy generation is not cost-competitive when the cost of safety measures is added to the generation cost. It caused misconception that renewable energy is low-cost energy. Many counties have introduced renewable energy, such as solar and wind power, but some researchers in the UK insist that these forms of electricity might be unavailable in the future due to climate change. Therefore, the UK is aware of this potential crisis and has determined that advanced examination has to start now about what should be done at such a time in the future.

The roles and responsibilities of human resource management in the UK’s civil nuclear management are as follows:

The IAEA Convention on Nuclear Safety was enacted in 1994. Article 9 of the convention specifies that the prime responsibility for the safety of a nuclear organisation lies with the holder of the relevant licence. While there is no published guideline on how licence holders should manage human resources, the UK government has delegated prime responsibility for the provision of human resources to the ONR, the regulatory body. The ONR is an independent public body accountable to Parliament through three ministries: (i) the Department for Work and Pensions for its governance, finance, and non-nuclear health and safety responsibilities; (ii) the Department for BEIS for the UK civil nuclear regulatory framework and policies; and (iii) the Ministry of Defence for nuclear safety and security at nuclear sites.

The Department for BEIS has responsibilities for ‘working across the oil, gas and electricity sectors to make sure the UK has a well-functioning, competitive and resilient energy system, and sufficient capacity to meet the needs of energy users in the years ahead’ (BEIS, 2017).

The CNRD, a subdivision of the Department for BEIS, is at the heart of ensuring the safety and security of civil nuclear sites. The directorate ensures UK nuclear emergency planning is robust and the threats posed by nuclear and radiological materials and expertise in vulnerable locations worldwide are minimized. CNRD also leads BEIS's work on resilience of the UK's energy supply, including cyber-related resilience, to prevent, where possible, significant breakdowns in the supply of electricity, gas or fuel to consumers and businesses.

[9] Magnox reactors are different type of reactors which is controlled by graphite and cooled by carbon dioxides. The safety feature is completely different from water reactors used in most of the world including the US.

The CNRD describes a position of Director of Civil Nuclear and Resilience as the 'lead on ensuring that the department has the capability and capacity to respond to emergencies and incidents, covering scenarios ranging from floods and bad weather through to severe accidents and widespread loss of the electricity supply'. Therefore, the Department for BEIS has responsibilities for human resources and competence.

The ONR is the regulatory authority for nuclear safety and conventional health and safety at licenced nuclear sites in the UK. The ONR was required in the Nuclear Installations Act, 1965 'to attach to each nuclear site licence such conditions as it considers necessary or desirable in the interests of safety and ONR may attach conditions with respect to the handling, treatment and disposal of nuclear matter'. The Licence conditions include human resources.

The training required to become an inspector or technical expert in specific fields is specified in the ONR's Nuclear Safety Technical Assessment Guide – Training and Assuring Personnel Competence (ONR, 2017); the Health and Safety at Work Act, 1974; and the Ionising Radiations Regulations (2017).

In a crisis, the COBR is channelled through the Department for BEIS as the lead government department (HM Government/The Scottish Government, 2015).

While the Scottish Government also provides inputs to the COBR as the lead government department, Scotland has a different structure from the emergency response structure of England and Wales, since the Scottish government works with the COBR, the Scotland Office, and other relevant departments in a crisis.

2.5.3. France

Before the Blayais flood in 1999, France's nuclear industry had not prepared for external threats, but it began to seriously consider external events after the accident. MINES ParisTech dealt with this accident as a case of failure of regulation and as a case of operator's improvement. The flood revealed EDF's failure to disclose information to the media in a timely manner, in addition to technical flaws in the design.

In response to this event, EDF reviewed the flood prevention and measures of all power stations in France, including a risk analysis of Bugey and Chooz nuclear power plants. Parliament also addressed this issue and presented a strong request to the representatives of local governments at the locations of nuclear power stations to play a central role in reassessing the preparedness for natural disasters. This led to an improvement in EDF's backup system. ASN incorporated flood risks and countermeasures in its guidelines, updated in 2013, as external threats. Communications teams were set up to provide the media and local communities with timely information, separate from technical teams responsible for collecting information and implementing countermeasures. In 2017, ASN ordered all four reactors of Tricastin nuclear power station to shut down temporarily since their flood measures were not satisfactory and could cause a severe accident such as Fukushima Daiichi NPS Accident if a huge amount of water flooded the reactor facilities from the intake source canal during a natural disaster.

In France, while a variety of natural disasters – including floods, earthquakes, droughts, volcanic explosions, cold waves and heat waves – could occur, the same measures are applied to all disasters regardless of whether they are internal or external events, so no special measures are required. The first step to prepare for natural disasters is to develop appropriate designs for preparedness. This provides the basis of all actions. When developing the design, every possibility should be taken into consideration, such as fires due to human factors in addition to natural disasters. Then, regional data on natural disasters should be consulted to determine the scale of floods, earthquakes, etc., that could occur in the target location. It is also important to learn lessons from other countries. Following the Chernobyl accident in 1986, France's nuclear industry – in cooperation with the government, regulator, operators, vendors, etc. – established the Groupe d'INTervention Robotique sur Accidents (INTRA) in 1988 to improve emergency response capabilities (Groupe INTRA, n.d.). Located at the Chinon nuclear power station, Groupe INTRA operates a fleet of robots that are equipped with a radiation protection mechanism and are operated remotely to respond to nuclear events. Groupe INTRA also conducts regular training.

As a part of an inspection of France's nuclear industry following Fukushima Daiichi NPS Accident in 2011, ASN called on EDF to establish FARN to increase safety – aiming to provide emergency support in terms of personnel and equipment at any nuclear power plant in France within 24 hours (Le Guen, 2014).

One of the missions immediately after a major disaster is to recover power supply, since it contributes to the reconstruction of local society. FARN is trained to function during emergencies. It is ready for action within 8 hours of an accident, it arrives at the site within 12 hours, and it completes the response within 48 hours.

FARN's objective is to intervene in all areas such as operation, maintenance and logistics on any French site. FARN set a target to get water and electricity in less than 24 hours in order to avoid core fusion and all release into the atmosphere. Its intervention is requested in the case of important infrastructure destruction and with several risks (radiologic and/or chemical).

FARN set teams such as a national team to recognise the situation and regional teams coming from the four regional centres. FARN teams are aiming for evaluating site situations, reinjecting water and electricity in the NPP, ensuring plug and play connections, supporting NPP operators, intervening in less than 24 hours to support the site. FARN's intervention is supported by three levels of organisations – local, regional, and national (EDF, 2013).

A hardened core notion has been designed and approved for implementation. This is a unique notion. It covers all technical systems, processes, and procedures. It also strengthens the robustness of any nuclear facility against extreme situations such as tornadoes, flooding, and seismic events. Hardened core notion is required to (i) stop the nuclear chain reaction and allow cooling to evacuate heat, (ii) control containment of radioactive materials (iii) manage the crisis.

EDF presented to ASN its proposal in June 2012 based on criteria defined with the IRSN (ASN, 2012).

Chapter 3

Opportunities and Barriers in Securing Resilience

The workshop was held for sharing information on the resilience of nuclear facilities based on lessons learned from experienced natural disasters. It also aimed at developing guidelines for resilience of the nuclear facilities against natural disasters which included information sharing on natural disasters in East and Southeast Asia and their impact on energy facilities and expected policy proposals.

The following documents are the findings from the workshop.

3.1. US

The US civil nuclear energy industry consists of three pillars: the domestic fleet, advanced reactors, and international markets. The demand for baseload electricity that is domestically generated, reliable/resilient, and clean energy sources will continue in the future. Nuclear will play an important role in contributing energy security, national economy and environment. However, nuclear reactors in the US have been facing early shutdown due to low gas price.

To help revive the nuclear industry, the DOE has programs such as the following:

- Public–private partnerships.
  - Small Modular Reactor (SMR).
  - Micro-reactors.
  - Smart fuels.
  - Advanced manufacturing for securing the supply chain.
- A Versatile Test Reactor.
- Fuel supply for Advanced Nuclear.

The DOE has communicated with students and stakeholders about the importance of nuclear energy (Making Nuclear Cool Again) (DOE, 2018). As educational outreach for students in the next generation. 17 Millennial Nuclear Caucuses were established inside the US and abroad. The environment and energy security were mentioned in high school textbooks. The DOE has explained the benefits of nuclear energy for people and has implemented a series of educational meetings for policymakers as leadership education.

3.2. Japan

Following Fukushima Daiichi NPS Accident, the Nuclear Risk Research Center (NRRC) was established in December 2014 to develop risk evaluation methodology for external events. The Japan Nuclear Safety Institute (JANSI) was established as a self-regulatory organisation in November 2012 JANSI is independent from public utilities and aims to promote nuclear safety.

Japan's probable natural disasters are following earthquakes, tsunami, flooding, volcanic eruptions, tornadoes/typhoons, and forest fires. The government develops the design criteria and guidelines for achieving high nuclear safety against natural disasters in cooperation with academia, public utilities, and industry. Nuclear facilities are protected against the following natural disasters:

- Earthquakes.
  ・Establish rigid design to maintain or reduce seismic response.
  ・Build combined structures and maintain low centre of gravity.
- Tsunami.
  ・Locate well above the maximum water level.
  ・Build sea walls and watertight doors.
- Volcanic eruptions.
  ・Secure the structural design, avoiding ash loading.
  ・Prevent the loss of dynamic component function from volcanic ash.
- Tornadoes/Typhoons.
  ・Secure the structural design from tornado/typhoon forces.
  ・Maintain robust building and protective structures for tornado missile effects.
- Forest fires.
  ・Build a fire break and thermal shield.

A five-layered safety design approach is defined in the IAEA Specific Safety Requirements (IAEA, 2016), which categorises the levels of defence as 'design basis' and 'beyond design basis'. Levels 4 and 5 require the prevention and mitigation of radiological release, even under significant 'beyond design basis' conditions.

Table 6: Defence in Depth Approach

Design Dase/ Beyond Design Base	Level of Defence	Objective	Essential designs
Design Base (DB)	Level 1	Prevention of abnormal operation and failures	Conservative design and high quality in construction of normal operation systems
	Level 2	Control of a abnormal operation and detection of failures	Limiting and protection systems and other surveillance features
	Level 3	Control design basis accidents	Engineering safety features
Beyond Design Base (BDB)	Level 4	Control of design extension conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Safety features for design extension conditions
	Level 5	Mitigation of radiological consequences of significant releases of radioactive materials	On-site and off-site emergency response facilities

Source: Author, based on IAEA (2016).

3.3. ASEAN and Asian Countries

Views on nuclear power vary widely by country in ASEAN and Asia. Some countries include nuclear energy in their future energy policies or have begun to develop rules and documents on nuclear energy. Others have not yet begun considering the introduction of nuclear energy due to lack of scientific technology and human resources, although they are aware that nuclear energy might be needed in the future because of the rapid increase in demand for electricity.

Mongolia, Malaysia, Cambodia and Lao PDR presented their status on development of nuclear program as well as their energy policy trends in the workshop. The following statements are the key messages from their presentation.

Mongolia announced the Mongolian Sustainable Development Vision 2030 (STATE GREAT HURAL OF MONGOLIA, 2016) and stipulated a nuclear introduction plan in a phased manner as follows:

- Phase 1 (2016–2020): Start preparations for using nuclear energy.
- Phase 2 (2021–2025): Complete preparation for using nuclear energy.
- Phase 3 (2026–2030): Start using nuclear energy.

Mongolia conducted infrastructure studies from 2010 to 2012, but they were insufficient. To proceed with the introduction of nuclear energy, more research work related to the IAEA's Milestones in the Development of a National Infrastructure for Nuclear Power (IAEA, 2015) are expected. In terms of international cooperation, the Nuclear Energy Commission of Mongolia signed a memorandum of cooperation on the construction of the Centre of Nuclear Science and Technology in March 2018 with Rosatom (Rosatom, 2018), aiming to develop mutually beneficial cooperation in civil nuclear energy use and design a blueprint for the centre.

Malaysia has experienced sporadically earthquakes because it is located outside the Pacific Rim of Fire, but it has a high frequency of floods due to two monsoons. The disaster management structure and disaster management level are stipulated in the Malaysia Disaster Management Reference Handbook (Center for Excellence in Disaster Management and Humanitarian Assistance, 2019). The disaster management levels are defined as follows:

- Disaster management level 1 (district).
  - Localised incident, controllable and has no probability to spread.
  - Disaster managed by authorities at the district level.
- Disaster management level 2 (state).
  - Incident covering two or more districts but no potential to spread.
  - Coordinated assistance at the state level to the affected districts.
- Disaster management level 3 (central).
  - Complex and covering a wide area or more than two states.
  - Greater financial, human resources, and asset coordination.

Malaysia's Nuclear Power Policy, approved by the Cabinet in July 2010, aimed to introduce nuclear energy by 2021. However, due to political direction change, the Minister of Energy, Science, Technology, Environment, and Climate Change (MESTECC) announced in November 2019 that Malaysia would not build nuclear power plants.

Nevertheless, the Malaysian Nuclear Agency established a Nuclear and Radiological Emergency Preparedness Plan; preparedness and response to reassure the public and take the necessary actions to mitigate the consequences of accidents. The plan is revised based on the rules and regulations in Malaysia as well as recommendations from nuclear organisations such as the IAEA and the Enforcement Authorities.

Cambodia has no plan to introduce nuclear energy. Challenges for the introduction of nuclear energy in Cambodia are as follows:

- Lack of human capacity and equipment in nuclear science and technological field.
- Lack of knowledge and experience of nuclear and radiation safety.
- Limited perception of policymakers.
- Lack of training in nuclear physics, radiation protection, inspections, safeguard techniques, emergency preparedness, and response.

The Lao People's Democratic Republic (Lao PDR) has no plan to introduce nuclear energy. However, it will require more baseload power sources, including nuclear energy, in the future – especially in the dry season – because the Lao PDR largely depends on seasonal hydroelectric power. Therefore, the Lao PDR has an intention on learning experiences and lessons of nuclear resilience in the developed countries.

Chapter 4
Policy Recommendations

The literature survey and hearing survey in the US, the UK, France and Japan have shown that each country has its own nuclear resilience law structures and measures. Each country has its own history of developing legal structures and measures based on the discussions on resilience triggered by natural disasters that occurred in that country. For ASEAN countries considering the introduction of nuclear power stations, the history of these countries is informative for developing legal structures and measures for securing the resilience of nuclear infrastructure against severe natural disasters.

The following section outlines findings and recommendations based on the characteristics of each country.

4.1. US

Independence. One of the characteristics of the US nuclear sector is the independence of the NRC as the nuclear regulator. Fair arguments are ensured because each sector agency is completely independent, e.g. the court has the right to express an objection to a decision by the NRC. Independence is also ensured inside the NRC, e.g. the chair of the NRC has the right to oppose a topic which almost all members agreed in the NRC.

Cost–benefit analysis. Another characteristic is the prevailing concept of a positive cost–benefit relationship – from the regulator to researchers and citizens. For nuclear resilience, based on a consideration of the break-even point at which the maximum benefit is obtained for the cost, discussion is concentrated on the optimum level which nuclear resilience against natural disasters should reach. In other words, a rational system has been built in which no extra measure is prepared when it is judged that no improvement of resilience worth the cost is obtained.

Communication. The NRC conducts regular communication with operators and local people at every level of its organisation and has built a system that enables all stakeholders to gain access to the latest information in a timely manner. Such constant efforts to ensure transparency, e.g. posting timely information on its Home Page, are the major factors in instilling confidence in operators and the public.

These three points are highly informative not only for ASEAN countries but also for Japan. Especially Japan could learn more from the experience of the U.S. when communicating with local people living near NPPs regarding restart of nuclear power stations after long-term out-of-service due to prolonged new safety requirements.

4.2. UK

Emergency preparedness. The discussion on electricity resilience started after the 2009 flu pandemic in the UK. Nuclear resilience was discussed comprehensively after Fukushima Daiichi NPS Accident. When a severe accident occurs and scientific insights are required, the Prime Minister calls the COBR, and the COBR asks the chief scientific adviser assigned by each ministry and agency for advice. The chief scientific adviser gathers scientists and experts to launch an urgent SAGE and conduct information collection and analysis to develop response measures.

Technical adaptation. The UK has used Magnox reactors in addition to light-water reactors until 2015. The UK imported nuclear resilience from the US; however, the UK has operated Magnox reactors as well as light water reactors. Thus, the UK modified nuclear resilience from the US to fit for the UK. For ASEAN countries considering the introduction of NPPs, modifying nuclear resilience of the US to fit own country is informative enough for developing law structures and measures.

Preparation of probable future natural disasters. Another characteristic of the UK is that it regards resilience as not only early recovery after a natural disaster but also preparedness for natural disasters in the future. Researches of natural disasters occurred in neighbouring countries are also incorporated since several nearby countries (e.g. the Netherlands and several areas in Europe) are located below sea level, and the expected sea level rise due to climate change is an imminent issue, although the UK has fewer natural disasters than other areas.

ASEAN countries have the opportunity to advance research and development for considering emergency response to probable future natural disasters on the assumption that the incidence of natural disasters increases due to climate change. Some researchers in the UK assumes that natural disasters will be stronger in the future, although these countries have had relatively few natural disasters so far. In addition, there is a lot of useful information that provides research subjects, e.g. studying measures to avoid the risk of renewable energy technologies such as solar and wind power generation becoming unavailable in the future due to climate change.

4.3. France

Possibly reviewing overseas incidents. Since France usually experiences a small number of natural disasters, before the accident at the Blayais nuclear power plant caused by a flood in 1999, no full-scale examination had been conducted on its preparedness against natural disasters. Research equipment and tools had been prepared for expected disasters at that time, but they had not been used. Since the flood, France has conducted extensive efforts to develop laws pertaining to nuclear resilience and to establish mature organisations, reflecting lessons learned from flood at the Blayais nuclear power plant and Fukushima Daiichi NPS Accident in Japan. France positively incorporates the experience of international events into emergency preparedness since it has experienced a small number of natural disasters. This offers lessons to ASEAN countries, which are facing various natural disasters.

Measures against natural disasters. Another characteristic of France is that it regards the measures against natural disasters and those against internal and external events as the same. Hence, the measures against natural disasters are examined and implemented together with internal and external events.

Training. France continues to review the preparedness in terms of equipment and is making a concerted effort regarding the education, training, and fostering of the human resources available in emergency situations. It also plans to enhance such efforts in the future.

4.4. Japan

The new safety requirements. Since Fukushima Daiichi NPS Accident, Japan has improved its safety awareness, ability to promote dialogue, and technological capability. The new safety requirements began to be implemented in July 2013, based on Defence in Depth – significantly raising the assumption level of natural disasters and reinforcing the measures for events which could result in the loss of safety functions through common factors in addition to natural disasters. Public utilities have started in-house discussions for improving safety. In addition, the government, local governments and utilities have tried to improve reliability through more frequent communication with local people as well as sharing information in a timely manner.

Investigation Committee and the Working Group on Electricity Resilience. Although Japan has experienced more natural disasters than Europe or the US, full-scale examination on electricity resilience began after a major blackout due to a series of disasters including heavy rains, typhoons, and the Hokkaido Eastern Iburi earthquake that occurred in 2018. In response to these events, in September 2018, the Ministerial Meeting on Emergency Inspection of Critical Infrastructure launched the Investigation Committee on the Major Blackout by the 2018 Hokkaido Eastern Iburi Earthquake and the Working Group on Electricity Resilience to conduct 132 issues inspections on the electric infrastructure and propose or develop countermeasures and policies. In addition, it decided to implement a 3-year emergency response plan for disaster prevention, disaster mitigation, and building national resilience from 2018 to 2020.

The Fifth Strategic Energy Plan (METI, 2018a)[10], revised and approved in the ministerial meeting, firmly maintains the necessity of the policy system that is extracted from '3E+S' (energy security, efficiency, environment, and safety) with an appropriate balance as the idea for a basic energy policy. While the importance of resilience is recognised through a series of disasters, the reduction of the public burden for safety and consideration of the environment continue to be important. Therefore, it is important to study comprehensive policies that include the above points in the future.

[10] In the Fifth Strategic Energy Plan, nuclear power is described as "Lower dependency on nuclear power generation to the extent possible" and "Restart of nuclear power plants and continuous improvement of safety" by 2030, and "One of the options for decarbonisation" and "Pursuit of safe reactors, development of back end technologies" by 2050.

Now the IEEJ would like to propose policy recommendations on how to proceed with nuclear resilience against natural disasters based on the progress in advanced countries.

In ASEAN and Asian countries, consideration of introducing nuclear power widely varies by country. While some countries consider introducing nuclear power as a future option, no country has concrete construction plans for nuclear facilities in the near future. However, some ASEAN and Asian countries have rules and guidelines for improving resilience, emergency plans, and preparedness against natural disasters.

As described above, each country has started to comprehensively examine the importance of nuclear resilience in response to large-scale natural disasters that occurred in their countries. On the other hand, both the frequency and type of natural disasters are low, especially in Europe. In the US, since the type of natural disasters that has occurred varies greatly depending on the location, various efforts have been implemented in each area. Japan has experienced various types of natural disasters so far, and their scale has been growing recently. ASEAN countries can select and incorporate laws and measures appropriate to each country from various efforts to mitigate the effects of natural disasters. It is appropriate to build a country-specific model to each country based on the activities and histories of the advanced countries and incorporate applicable lessons based on their own predictions in the future. In addition, enhancing nuclear resilience by preparing an academic field to conduct discussions about nuclear resilience amongst advanced counties and ASEAN countries is strongly recommended for all countries that are considering the introduction of nuclear power or where experimental nuclear facilities are already in operation.

Issues regarding the enhancement of nuclear safety and emergency preparedness and response are addressed in the Asian Nuclear Safety Network (Asian Nuclear Safety Network, n.d.), an international organisation in Asia under the umbrella of the IAEA. Issues related to the resilience against natural disasters should be included in the Asian Nuclear Safety Network (Asian Nuclear Safety Network, n.d.) as one of the high priority issues to achieve better communication and collaboration amongst Asian countries.

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