RESILIENCE AS A SYSTEM REQUIREMENT FOR ENERGY SUPPLY: AN INTERNATIONAL COMPARISON

A study commissioned by BDEW – German Association of Energy and Water Industries

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In case of any discrepancies between the two versions, the original German version shall prevail.

1 EXECUTIVE SUMMARY

Background and Target Audience of this Report

This report is a study prepared by HIC Consulting with the support of the BDEW. However, the study expressly does not set out any association positions. The recommendations for action and analyses set out in the report are intended to serve as a basis for discussion for policy-makers and the energy sector in Germany.

Current Situation

The German and European energy supply faces a changed threat landscape. The energy crisis resulting from Russia’s war of aggression against Ukraine, hybrid attacks on critical infrastructure and new import dependencies have established resilience as a key objective of energy policy alongside decarbonisation and cost-efficiency. Germany and the EU have already responded to this: examples include LNG diversification, increasing gas storage levels, the implementation of NIS-2 and the KRITIS umbrella law, power station reserves under the Energy Industry Act (EnWG), and proposals currently under discussion such as the sector’s cooperative security networks. Market mechanisms and corporate responsibility are key sources of resilience in Germany and form the foundation upon which any further development should be built.

At the same time, forward-looking, cross-departmental strategic resilience planning still has room for improvement when compared internationally. Operational crisis preparedness is robustly established at both European and national levels. The strategic, cross-sectoral planning level, however, has not yet been sufficiently developed. Responsibilities are spread across a large number of bodies, with no clear lead agency for energy resilience. Stress scenarios have so far only been partially incorporated into the existing planning instruments.

Methodological approach

The debate on the potential for developing Germany’s resilience strategy in the energy sector can benefit greatly from an international comparison. The study therefore analyses six core countries (Finland, Sweden, Japan, the United Kingdom, Poland, Lithuania) and three case study countries (Israel, Ukraine, China) across the four areas of action: institutional frameworks and cooperation structures, scenarios and planning instruments, strategic reserves, and network and system architecture. The selected countries are expressly to be understood as case studies and not as direct models. They differ from Germany – in some cases substantially – in terms of market structure, ownership structures of energy suppliers, geographical location, security and defence policy traditions, and federal structure. These structural differences limit the direct transferability of individual solutions. The value of the country case studies therefore lies less in serving as direct templates and more in their function as a mirror and a space for exploring possibilities, within which Germany’s options for action and questions of implementation become more clearly discernible.

Overview of countries

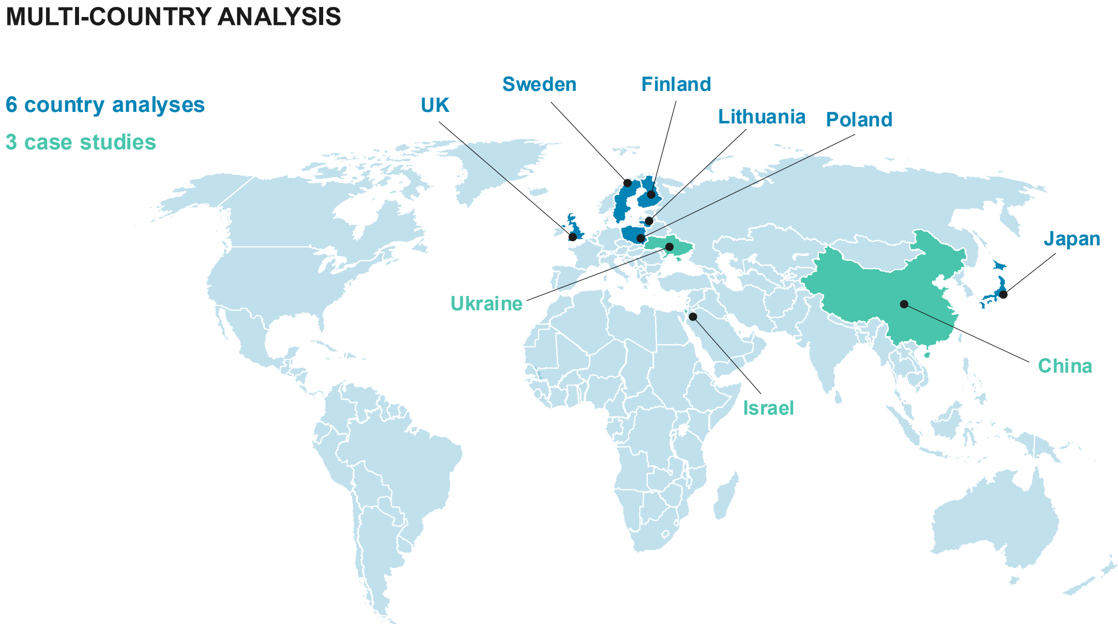

Figure1-1 : Country Overview

Table1 : Country Overview

Criterion	DE	FI	SE	JP	UK	PL	LT
Import depen-dency across all energy sources	~67 %	~33%	~27%	~85%	~40%	~45%	~66%
Govern-ment structure	Federal	Decentralised central government (strong local authorities)	Decentralised central government (strong local authorities and regions)	Centralised state (prefectures)	Centralised state (devolution)	Centralised state	Centralised state
Policy approach to energy resilience	Fragmented	Bottom-up	Hybrid	Hybrid	Hybrid	Top-down	Top-down

Sources: Eurostat 2026[1] , DUKES 2025[2] , METI / Agency for Natural Resources and Energy 2025[3]

Policy recommendations and further analysis findings

The report derives three overarching policy recommendations regarding the institutional framework from the international comparison, as well as twelve further, broad-based analysis findings that do not specifically relate to the German context.

Policy recommendations

Institutional framework & cooperation structures

- **Cross-departmental leadership on resilience:** Establishment of a permanent, cross-departmental body for energy resilience with a decision-making and steering mandate vis-à-vis the specialist authorities and acting as an interface with the energy sector, thereby closing the gap in acute crisis coordination.
- **Formalised resilience dialogue with the energy sector:** Establishment of a permanent, formalised exchange between the state and the energy sector, involving structured sharing of situational assessments, joint exercises and annual gap and status reporting, which goes beyond existing working groups.
- **German resilience strategy as a political framework:** Development of a high-level strategy that establishes resilience as an extension of the security of supply objective – as a dimension of equal importance alongside decarbonisation and cost-efficiency – and provides a frame of reference for planning instruments in terms of protection targets, time horizons and endurance requirements.

Further international analysis results to stimulate discussion

Scenarios and planning tools

- **National Energy Risk Inventory:** A consolidated, regularly updated risk inventory for energy infrastructure to serve as a common reference point for downstream planning tools.
- **Stress scenarios in grid development planning:** Examination of extending the scenario framework for electricity and gas grid development planning to include stress cases, in order to proactively plan for redundancies.
- **Extension of gas risk provisioning to include stress scenarios:** Supplementing gas-related risk, prevention and emergency response measures to include scenarios beyond the supply disruptions already factored in.

Strategic reserves and stockpiling

- **Mandatory reserves across all energy** sources **with their own legal basis:** mandatory reserves exceeding the EU minimum requirements for all energy sources relevant to supply, managed by a government body or a mandated agency.
- **Resilience-driven reserves for strategically important power stations:** A dedicated, resilience-driven form of reserve for strategically important power stations, separate from market- and grid-related reserves.
- **Resource diplomacy and institutionalised energy partnerships:** Institutionalised safeguarding of long-term supply relationships for gas, LNG and, in the future, hydrogen, with diplomatic support for importers.

Grid and system architecture

- **Embedding resilience-building through renewable energy expansion:** Treating increased resilience as an equally valid justification for renewable energy expansion, combined with a shift towards generation close to consumption and distributed generation.
- **Expanding resilience criteria in capacity market design:** Adding criteria such as decentralisation, black start capability and geographical distribution to make the impact of decentralised generators and storage facilities more visible.
- **Fuel flexibility as a design requirement:** The ability to operate using a liquid secondary fuel as a criterion for strategically important plants, based on their systemic importance.
- **Prioritisation system for critical electricity consumers:** Work with the energy sector, the federal states and local authorities to examine the introduction of a prioritisation system for consumers of particular social importance below the threshold for the emergency regime.
- **Self-sufficiency for several days as a target:** Discuss the establishment of a self-sufficiency target (e.g. the aim of self-sufficiency for several days) at the distribution level as a framework for local authority crisis preparedness regarding electricity, gas and heating.
- **Strengthening cross-border interconnectors and repair partnerships:** Resilience-oriented strengthening of cross-border electricity and gas interconnectors, as well as European-coordinated repair partnerships for critical network components.

Conceptual framework

In addition to the proposed courses of action, the study provides a framework that remains valid regardless of the political implementation of individual proposals. Three elements are worth highlighting here. Firstly, the study systematises the diffuse field of potential crisis situations into a typology comprising six crisis categories. Whilst these categories are not strictly distinct in every individual case, they organise the discussion and enable a structured comparison between very different crisis scenarios.

Secondly, the study provides a scenario toolkit that describes each scenario using seven parameters: trigger class, affected system level, time dimension, geographical scope, escalation level, amplifier profile and recovery options. This toolkit is designed as a proposed tool enabling the energy sector, the Federal Network Agency (BNetzA), transmission system operators or political stakeholders to consistently parameterise their own context-specific scenarios without having to commit to a fixed list of scenarios. Four illustrative sample scenarios demonstrate its application but are not intended to be prescriptive.

Thirdly, the international comparison identifies seven recurring best-practice approaches – institutional coordination, a strategic framework, public-private cooperation, stockpiling beyond EU minimum standards, managed diversification, stress scenarios, and regional resilience and stand-alone operation embedded in planning – which, as an analytical framework, not only enable a comparison between the six core countries but also provide relevant concepts for the German debate. These three building blocks – crisis typology, scenario toolkit and best-practice approaches – are intended as a contribution to the technical structuring of the resilience debate in Germany and can be utilised even if individual proposals for action are not pursued further.

Guiding principles for further action

To translate individual proposals into concrete initiatives, the study proposes the following guiding principles: resilience policy should build on existing German and European structures rather than duplicating them. Market mechanisms and corporate responsibility must be recognised as key sources of resilience. The entrepreneurial freedom of action of the member companies must be preserved. Additional bureaucratic burdens should be kept to a minimum, and sustainable funding must be ensured. Furthermore, the implementation must comply with EU law, be compatible with federalism and take place in close consultation with the sector. A blanket application of the approaches from the countries examined is expressly not recommended.

Outlook

The international comparison yields insights into the approach that are also relevant to the German debate: individual measures can bring about improvements in resilience relatively quickly. However, in the countries examined, resilience-building has rarely taken place as a one-off reform, but predominantly as a long-term, incremental process spanning several parliamentary terms. Poland's gas diversification spanned around sixteen years; the Finnish pool system has evolved over several decades; and the foundations of the Swedish Styrel system date back to the 1970s. Furthermore, strategic resilience does not arise solely through policy instruments, but requires a risk culture supported by politics, the civil service and the business sector, one that underpins strategic preparedness even outside times of acute crisis. For the German debate, this means that strategic resilience can be built up not so much through individual major reforms as through the formation of a coherent, cross-party and cross-stakeholder consensus spanning several parliamentary terms. This study is intended as a contribution to this development.

2 BACKGROUND AND APPROACH

German and European energy supply faces a changed threat landscape. Geopolitical upheavals and growing vulnerability, alongside decarbonisation and cost-efficiency, have brought resilience into focus as a key objective of energy policy. **Significant progress in operational crisis preparedness** (e.g. regarding KRITIS/NIS-2, LNG diversification) are, however, set against a strategic framework that largely operates in 'peace dividend' mode and shows no sign of a forward-looking, cross-departmental **strategic resilience strategy**. The transition to integrated resilience planning with objective criteria, as binding as climate targets, is therefore advisable. This reorientation should be cost-conscious, low-bureaucracy and EU-compatible, and must not be in open conflict with climate policy. This study aims, in particular through the analysis of approaches taken by other countries, to identify possible courses of action for integrating resilience into the medium- and long-term planning instruments for energy infrastructure.

2.1 Changed risk landscape

The foundations on which the German and European energy supply systems have been built over decades now apply only to a limited extent. Russia's war of aggression against Ukraine since February 2022, the abrupt end to pipeline gas supplies, a hybrid threat landscape, and supply disruptions arising from the conflict between the US and Iran have shaken the assumption of a predominantly peaceful, rules-based energy order. The Federal Office for the Protection of the Constitution notes that, against the backdrop of **'global disorder'**, state actors and their proxies are exerting influence on Germany using the full range of hybrid instruments.[4] Energy infrastructure is a particular focus of attention in this context. The Federal German Government itself now assumes there is an "abstract threat to critical infrastructure, including energy infrastructure, which is particularly in the public spotlight", and has, for the first time, adopted the

KRITIS umbrella law to establish a uniform framework for its physical protection. The security situation is increasingly being described as an intermediate state between normal operations and an acute crisis, including by Federal Chancellor Friedrich Merz.[5]

The 2022 bombing of the Nord Stream pipelines is a particularly clear illustration of the changed risk landscape; it directly exposed the **vulnerability of Europe's energy infrastructure**, whilst the neighbouring states were unable to prevent the attack or investigate it promptly.

Following the cessation of Russian pipeline gas supplies, Germany has become one of the world's largest importers of LNG – a development linked to **new dependencies** on a small number of market-dominating players, on maritime transport routes and on LNG import infrastructure.[6] At European level, the Commission states in its report on the state of the Energy Union that Russia's use of energy supplies as a political tool continues to threaten Europe's security of supply and, consequently, economic stability and growth in the EU.[7]

Furthermore, the **digital threat landscape** facing the energy sector is intensifying. In its status report, the Federal Office for Information Security describes the IT security situation in Germany as 'still tense'.[8] State-sponsored hacker groups from Russia, China, North Korea and Iran have specifically targeted the energy sector, amongst others. The increasing digitalisation of energy generation, transmission, distribution and consumption is creating a growing surface area for attacks.

The risk scenario outlined above should not be viewed in isolation, but rather as a reflection of a deeper shift in the international order, in which **energy** is increasingly treated as **a strategic lever** rather than primarily as a market-based commodity. Open and integrated energy markets are increasingly being replaced by a state-centred model for the organisation of national energy systems and international energy relations.[9] Furthermore, the world order is becoming less and less cooperative: instead of multipolar cooperation, a competitive multipolar world (dis)order is emerging. Fragmentation arises from protectionism, competition for value creation and control over territories, energy flows and infrastructure. As a result, a power politics can be observed in which military access to territories and resources is also becoming an increasingly visible option for some actors. For Germany and the EU, this fragmentation means, first and foremost, that the extent of their own **dependence on imports** not only persists but has also undergone a qualitative change. The phase-out of Russian pipeline gas supplies has not eliminated these dependencies. Another significant dimension of this fragmentation concerns the **value chains of the energy transition** itself. However, this is to play only a secondary role in this study, as the focus is on direct threats. A halt to supplies of Chinese solar modules or battery systems, for example, would jeopardise long-term transformation goals, but would not directly threaten energy supply.

2.2 Approach and definition of terms

This changed risk landscape has a significant implication for German energy policy: it should move **beyond merely ensuring the direct security of individual plants and systems** – and making decisions on energy supply security without a long-term, coherent strategy – to **developing** and implementing dedicated **planning and management tools for security of supply** that are commensurate with the new situation. This can be aptly summarised under the term **'resilience planning'**, which has so far existed in Germany only in a fragmentary form at best. This shortfall provides the impetus and necessity for the present study.

Definition of resilience

In the discourse on energy policy, **'resilience'** has become an umbrella term encompassing a broad spectrum of very different phenomena and levels of action – ranging from the physical security of individual facilities, through cyber defence at plant operators, to strategic fuel stockpiling at national level. This **conceptual ambiguity** is unsustainable, as it suggests that a single framework of measures could address the entire range of vulnerabilities. This study therefore adopts a different approach and establishes at the outset which aspect of the concept of resilience is being examined – and which is deliberately excluded.

Conceptually, the study builds on the established **understanding of resilience**, as developed, for example, in the position paper 'Resilience of Digitalised Energy Systems'[10] by acatech, Leopoldina and the Akademieunion: Resilient energy systems are not characterised by the complete absence of disruptions, but by their ability to remain **operational** even in the face of severe and sometimes unforeseen disruptions, to recover quickly and to learn structurally from crises. The VDE policy paper 'Greater Resilience for Electricity and Communications Networks in Germany'[11] complements this perspective by addressing the technical dimension **of interdependencies** between energy and communications infrastructures and emphasises the need to understand **resilience as an integrative design principle**. Together with further preparatory work, including that carried out by the BDEW (see below), these two publications form the technical framework on which this paper is based.

Within this understanding of resilience, a distinction is made between two levels of action, which are often conflated in the political debate. At the **operational level** lie the obligations of individual operators regarding the physical protection of their facilities, IT and cyber security, incident management and reporting requirements. Significant progress has been made at this level in recent years. The **KRITIS Framework Act** provides, for the first time, a uniform, cross-sectoral legal framework at federal level for the physical protection of critical infrastructure, which implements the EU Directive on the Resilience of Critical Infrastructure (CER Directive) and obliges operators to carry out risk analyses, draw up resilience plans and meet minimum standards based on an all-hazards approach.[12] In parallel, the **NIS-2 Implementation Act** addresses cyber resilience and sets out uniform requirements for the IT security of critical infrastructure. The operational level thus has – despite the remaining implementation work – a sufficient regulatory framework.

At the **strategic planning level**, the situation is different. Here, the focus is not on which protective measures an individual operator must take at its facilities, but on the upstream question of whether and how resilience criteria are incorporated into the instruments used to plan, dimension and regulate the energy infrastructure in the medium and long term. Unlike operators' obligations, this level has not yet been subject to a uniform resilience regime. Key planning instruments continue to operate predominantly on the basis of a 'base-case' scenario and efficiency targets. Stress scenarios, geopolitically motivated supply disruptions or deliberately induced outages have so far only featured sporadically in these instruments. It is precisely here, in the authors' view, that there is a **conceptual gap** that this study aims to address.

Against this background, the present study focuses on what is hereinafter referred to as **strategic resilience planning**: the systematic integration of resilience criteria into the medium- and long-term planning instruments for energy infrastructure, including the associated regulatory framework and European integration.

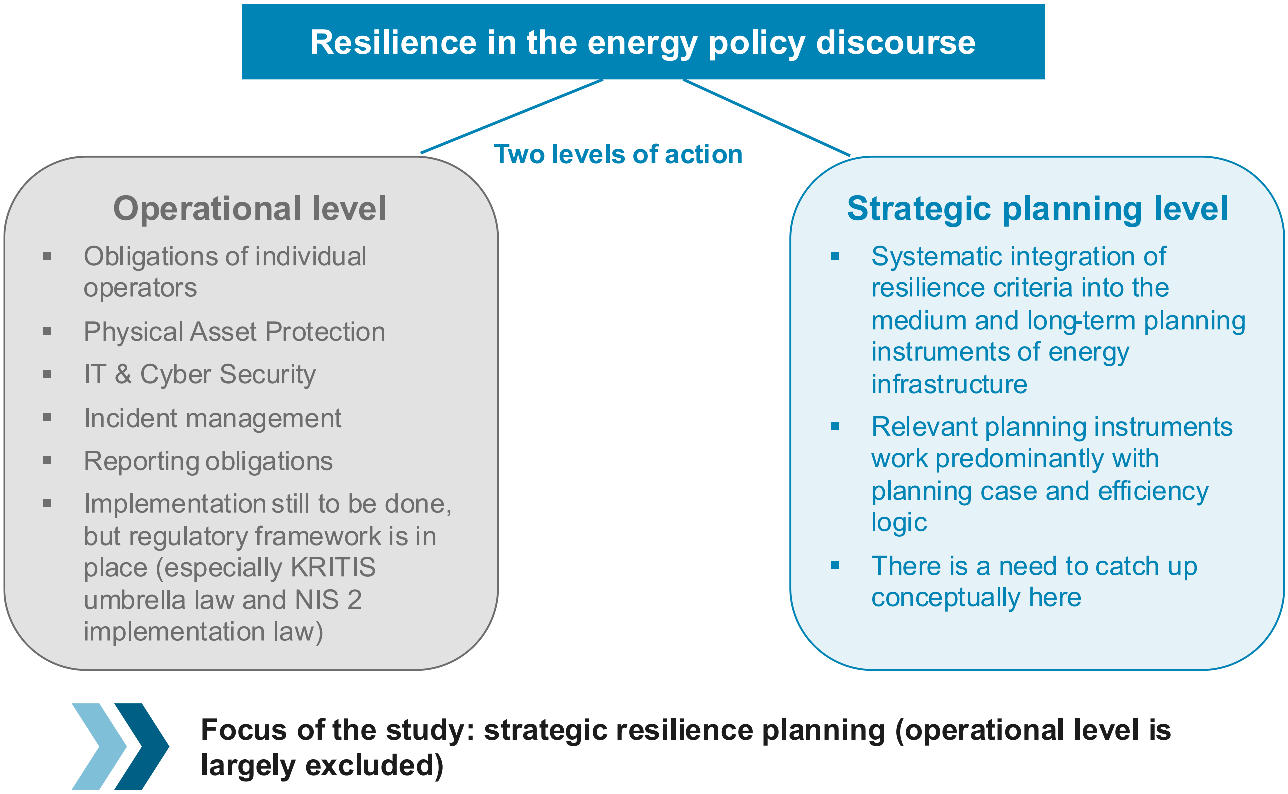

Figure2-1 : Definition of the term 'resilience' in the energy context

2.3 Study design and methodology

The aim of this study is to develop concrete **recommendations** for action regarding the integration of resilience criteria into German energy policy. It adopts a practice-oriented approach: rather than repeating foundational research, it focuses on **international experiences and best practices** and draws conclusions from these to inform recommendations for action.

The BDEW is already actively promoting the issue of resilience as part of its current activities. These include, for example, proposals for establishing cooperative security networks on a voluntary and regional basis, the ongoing discussion on vulnerability analysis, and the sector-specific energy resilience standard. These approaches are characterised by cooperation, a practical focus and coordinated structures. The BDEW's in-depth engagement with issues of security of supply and energy resilience is also reflected in various **publications** released over the past few years. This preparatory work serves as a conceptual and analytical **starting point**. The BDEW discussion paper 'Resilience in the Energy Sector: Areas for Action and Needs'[13] establishes **resilience as an overarching concept** comprising three core capabilities: absorbency (maintaining system continuity in the event of a disruption), recoverability (returning to operational performance following a disruption) and adaptability (long-term adaptation and learning by the system).

The fundamental principles of a resilient energy system include the three-pronged approach of anticipating potential shocks and crises, preparing for effective crisis management, and continuous monitoring. The following are identified as key areas for action: protection of critical infrastructure, resilience of the electricity system, resilience in the field of gaseous energy sources, supply chains and raw materials for the production of clean technologies, and climate resilience of energy infrastructure. Based on a position paper, the BDEW has presented a catalogue of **10 proposals for strengthening the resilience** of critical infrastructure in the energy and water sectors.[14] The BDEW publications 'Nexus: Raw Materials, Intermediate Products and the Energy Transition'[15] and 'Resilience of Supply Chains for Raw Materials, Energy Transition Technologies and Components in the Energy Sector'[16] explicitly address the issues of **critical raw material dependencies** and **dependencies on key technologies for the energy transition**.

Furthermore, the BDEW has already explicitly addressed the issue of gas supply resilience. The position paper 'Securing and Diversifying Gas Supply'[17] focuses on the **gas procurement side** and addresses, in particular, the geopolitical and trade policy dimensions. Essentially, it sets out the key framework conditions for diversified gas procurement. The position paper 'Concept for Gas Supply Security and Further Development of Instruments'[18] supplements this by addressing the issue of **gas storage level targets** at national and European level. Within this framework, the strategic gas reserve is identified as a suitable instrument for government intervention to provide targeted protection against acute emergency situations (caused by unexpected risks and external shocks). The design of a strategic gas reserve is further elaborated in the recently published position paper 'Gas Supply Security: Design of a Strategic Reserve to Safeguard Against Acute Emergency Situations and Extreme Events'[19] .

This study builds on and complements these publications. Its specific contribution lies in systematically linking the existing conceptual foundations with concrete international experiences, as well as in deriving possible courses of action.

The scope of the study was defined through a **scoping process** carried out jointly with the BDEW. In the process, the key areas for action were identified. Consequently, the study deliberately excludes topics that are either already addressed by specific regulations or dealt with in parallel processes: physical plant security and operational operator obligations – regulated by the KRITIS umbrella law – are not examined in depth, nor are cybersecurity under NIS-2, municipal heating planning, or climate adaptation in the narrower sense. Overarching planning instruments such as the Climate Protection Act, the system development strategy and the long-term scenarios are not dealt with separately, but are only taken into account insofar as they relate to the core areas of action. In terms of content, the study therefore focuses on the four remaining **core areas of action**:

- Institutional Framework & Cooperation Structures
- Planning tools & scenarios
- Strategic Reserves & Stockpiling
- Network & System Architecture

The study begins with a brief summary of **the resilience structures that** currently **exist** at both the German and European levels. This serves primarily to outline the status quo and, building on the summary provided, to identify the areas in which the current resilience structures have gaps.

At the heart of the study is an **analysis of international benchmark models**. To this end, it systematically sets out how the selected countries integrate resilience into their energy planning. The comparative analysis is presented in **six country chapters** covering the following countries:

- Finland
- Sweden
- Japan
- United Kingdom
- Poland
- Lithuania

The **countries** were selected on the basis of three key criteria: (1) comparability with Germany in terms of market structures and geopolitical situation, (2) documented experience of integrating resilience objectives into energy planning, and (3) coverage of different approaches.

Each country is generally examined using a standardised **analytical framework** based on the four core areas of action mentioned above. However, the application of the analytical framework is adapted to each country and prioritised accordingly. The country chapters focus on the key aspects that have emerged as **best-practice examples** within the respective contexts of the countries examined. In addition to the in-depth analysis provided in the six country chapters, specific experiences from Israel, Ukraine and China are also presented in the form of three digressions. The country analyses are based on official strategy documents, legislative texts, regulatory decisions and academic literature. With regard to the country analyses, it should be noted that the framework conditions in the countries under consideration vary considerably and, as a result, objectives and the choice of instruments differ. Differences compared with the situation in Germany exist, amongst other things, with regard to the historically shaped understanding of security and defence, competitive structures in the energy market, dependence on imports, and the state's ability to intervene in or own strategic energy companies.

The document analysis and desk research were supplemented by seven **expert interviews** involving 13 participants. These interviews focused primarily on representatives from the countries analysed. These guided expert interviews lasted between 45 and 60 minutes each and served a dual purpose: on the one hand, to validate and expand upon the country findings; on the other, to identify avenues for action that go beyond the approaches already developed in the preliminary phase. The key findings from the interviews are incorporated directly into the country chapters.

The panel of experts for the expert discussions comprises the following individuals and organisations:

- Finland: A senior decision-maker at the Finnish Ministry of Economic Affairs and Employment (TEM), who wishes to remain anonymous
- Sweden: Lars Nordström, Professor of Information Systems for Power System Control at KTH – The Royal Institute of Technology, Stockholm, Sweden
- Japan: a six-member team from the Japan Electric Power Information Centre (JEPIC), an organisation within the Japanese electricity sector dedicated to information exchange, analysis and research on the energy sector.
- United Kingdom: Deborah Petterson, Director of Resilience and Emergency Management at the UK's National Energy System Operator (NESO).
- Poland: two experts from the 'Energy and Resilience' team at the Casimir Pulaski Foundation (a Polish think tank focusing on security policy in Central and Eastern Europe), who wish to remain anonymous
- Lithuania: a senior policy analyst at the Government Strategic Analysis Centre STRATA, who also wishes to remain anonymous
- Israel: an independent energy expert, who has also requested anonymity, with leadership experience in both the energy sector and the Israeli Defence Forces

Following the international country analyses, there is a section devoted explicitly to the topic of **scenarios**. This is justified by the central role that scenarios play as the basis for further resilience planning steps. Scenarios can be used both as stress tests and as a benchmark for measures. Based on the results of the country analyses, the scenarios are first categorised into risk groups. This is followed by the parameterisation of example scenarios for the German context. This includes a **'scenario blueprint'** and the development of **model scenarios**. These model scenarios have no prescriptive aim and should not be understood as direct proposals; rather, they serve as examples to illustrate the dimensions in which scenarios can be developed. In addition, the report briefly addresses the potential **institutional embedding** of scenarios within the German context.

Finally, based on the country analyses and expert discussions, **policy recommendations** for German energy policy are identified. To this end, policy recommendations in the policy area 'Institutional Framework & Cooperation Structures' are outlined and supplemented by analysis results relating to the other policy areas (Planning Instruments & Scenarios, Strategic Reserves & Stockpiling, Grid & System Architecture). In addition, a brief comparison is made between the policy recommendations and further analysis results and the model scenarios.

3 GERMAN AND EUROPEAN RESILIENCE STRUCTURES

In order to identify targeted best-practice examples for German energy policy and to develop productive ideas for the **further development of resilience planning**, it is necessary first to examine the **existing resilience structures** within the national and European frameworks.

As explained in Chapter 2.2 , a distinction must be made between **two levels of action**. On the one hand, there is the **operational level**, which is characterised by a narrower understanding of resilience ('security of supply'). On the other hand, there is the **strategic planning level**, which, in contrast to the more fragmented approach of the operational level, is comprehensive and forward-looking in nature. In the following, the existing European and national resilience structures in the energy sector at both levels will be briefly outlined from this perspective.

3.1 European resilience framework

Resilience is a key theme of **the Strategic Foresight Report 2025** published by the European Commission on 11 September 2025. The concept of **'Resilience 2.0**' is intended to bring strategic resilience planning to the fore across all policy areas of the European Commission.[20] In the field of European energy systems, the **EU Risk Preparedness Regulation** (Regulation 2019/941) for the European electricity sector, the European regulations and directives on **energy stockpiling** – in particular the far-reaching **EU Gas SoS Regulation** (Regulation (EU) 2017/1938), and the **Critical Entities Resilience (CER) Directive** (EU 2022/2557) are of key importance.

Since 2022, the **CER Directive** has established a European framework for the resilience of critical infrastructure through a broader, risk-based approach. It aims to **improve the physical resilience of critical infrastructure** in order to prevent systemic disruptions, and also covers the energy sector. The CER imposes obligations on Member States to identify critical infrastructure and define responsibilities, as well as operator obligations for energy companies classified as critical. The CER is implemented at national level via the aforementioned KRITIS Framework Act. As explained, the KRITIS Framework Act – and thus also the CER – fall **outside the scope of this study** due to their operational nature.

The European Risk Preparedness Plans

Since 2019, Member States within the European Union have been subject to a legal obligation under EU law to carry out preventive **risk, crisis and resilience planning in the electricity sector** in accordance with the European **Risk Preparedness Regulation** (Regulation (EU) 2019/941). This obliges Member States to draw up **national Risk Preparedness Plans** (**RPPs**).

Among other things, the **RPPs** must set out **specific measures** to prevent and manage electricity supply crises, as well as stipulate **regular risk analyses**. These measures include grid stabilisation measures, the establishment of reserve capacity, the introduction of cross-border coordination mechanisms, and the design of procedures for prioritising critical infrastructure. This serves to identify potential **electricity crisis**

scenarios and is intended to promote regional and **cross-border cooperation** in resilience efforts, in order to reflect the European nature of the single electricity market and to prevent contagion effects.

The Risk Preparedness Regulation therefore also requires that the national crisis preparedness measures in the electricity sector of the Member States be designed to be **EU-compatible**. However, the specific requirements for the RPPs are to be understood as **minimum standards**; each country is free to go beyond the specific requirements of the European framework in its national resilience policy.

Another element of the Regulation is the introduction of **Regional Coordination Centres (RCCs**), which carry out short-term ('week-ahead' to at least 'day-ahead') regional adequacy assessments.[21] 'Adequacy' assessments in this context mean that regular checks must be carried out to determine whether the available generation and grid capacities are sufficient to reliably meet the load forecast in the short term. This involves making realistic assumptions about possible outage, weather and grid restriction scenarios. The aim is to identify at an early stage whether a **supply shortfall** is emerging across an entire region.

The Risk Preparedness Regulation also includes **information and reporting obligations** towards the European Commission. The European Commission also collects the RPPs submitted by the Member States, thereby providing an overview of electricity crisis preparedness within the European Union.[22]

In line with the definition used in this study, the Regulation is primarily **of an operational nature**. Above all, it sets out requirements for the RPPs to be drawn up, which in turn describe **reactive crisis management in the electricity sector**. The regular risk analyses focus solely on the **short-term** stability of the regional electricity grid. Nevertheless, the RPPs represent a significant step towards enhancing the resilience of the European electricity grid, as they also introduce **strategic elements** into grid planning: risk profiles and catalogues of measures are systematically incorporated **into national planning cycles** through the RPPs. **Europe-wide cooperation** and a European best-practice approach to ensuring regional electricity grid stability are also promoted through the comparison of plans and 'benchmarking' via the European Commission's comments on the plans.[23]

EU rules on energy stockpiling, capacity and strategic reserves

In **the electricity sector**, the European Union has established a **framework for capacity mechanisms** through the **Internal Electricity Market Regulation** (Regulation (EU) 2019/943), enabling Member States to remunerate additional generation capacity in order to ensure security of supply. However, these mechanisms may only be **used as a last resort** if market distortions cannot be remedied by other means.[24]

A stockholding regime has been in place for **petroleum products** for decades: **Directive (EU) 2009/119/EC** requires all Member States to maintain minimum stocks of crude oil and petroleum products equivalent to at least 90 days net imports or 61 days domestic consumption – whichever is the greater. The aim of this regulation is to ensure a high level of security of supply through transparent mechanisms based on solidarity between Member States, which enable the coordinated release of reserves in the event of supply disruptions.[25]

In **the natural gas sector**, the EU has, for the first time, established a security regime through the **EU Gas SoS Regulation** (Regulation (EU) 2017/1938), which covers regional risk groups and, above all, includes the obligation to carry out a national **risk assessment**, draw up national **prevention and emergency plans**, and implement a binding **solidarity mechanism**. Following the 2022 energy crisis, this regime was most recently further supplemented and strengthened by Regulation (EU) 2022/1032: Member States have since been obliged to gradually fill their gas storage facilities to at least 80 or 90 per cent before the heating season; at the same time, the cross-border use of storage capacity and European coordination of security of supply have been strengthened.

3.2 German resilience framework

The **German resilience framework** is characterised by the **operational implementation of European directives**, on the one hand through the aforementioned KRITIS approach, and on the other hand by the **Risk Prevention Plan** (RVP, the German RPP), last updated by the BMWE in 2023, relating to **electricity supply risks**, as well as the **prevention and emergency plans** concerning national **gas supply security** and further **regulations on energy stockpiling**.[26]

The national risk prevention plan in the electricity sector

The **RVP** covers **regional and national scenarios** for **electricity supply crises**. To this end, the BMWE cooperates with the four transmission system operators (TSOs) and selected distribution system operators (DSOs) deemed to be key players. Under Paragraph 11 et seq. of the Energy Industry Act (EnWG), responsibility for the system lies with the TSOs. The TSOs act as system operators and network operators of the electricity grid, whilst the Federal Network Agency (BNetzA) acts as the system regulator.

The RVP implements the provisions of the EU Risk Preparedness Regulation. It clarifies the tasks and responsibilities relating to the **security of supply of the electricity grid**, procedures and measures to be taken in the event of an electricity supply crisis, and emergency tests. It also describes **prevention and preparedness measures** in the face of selected crisis scenarios. At regional level, **'blackout' exercises** for the electricity grid are explained. A **Crisis Coordination Centre (KKS)** within the BMWE is described; however, this is only intended to convene in the event of a crisis.

By incorporating national scenarios for the energy sector, the RVP includes **strategic elements**, as resilience criteria – such as the ability to withstand national scenarios – are integrated into the medium-term crisis preparedness of the electricity grid. It outlines forward-looking load management, supply priorities and emergency mechanisms in the electricity sector. Nevertheless, the plan's **focus** remains at the **operational level**: it primarily covers the immediate roles, procedures, reporting channels and obligations of network operators, as well as ad hoc responsibilities in the event of a crisis. **Strategic resilience planning**, in the sense of forward-looking, resilient network planning, is, by contrast, addressed only to a limited extent.

Implementation of the EU Gas SoS Regulation (Regulation (EU) 2017/1938)

The so-called **EU Gas SoS Regulation** obliges the Member States of the European Union, in particular, to implement three **national resilience measures** relating to the national gas network: a comprehensive **risk assessment** , a **prevention plan** containing specific precautionary measures, and an **emergency plan** governing reactive crisis management.

The national **risk assessment on measures to ensure a secure supply of natural gas** (SoS Regulation) is carried out and updated every four years by the Federal Network Agency (BNetzA).[27] To this end, the BNetzA examines, amongst other things, how market participants structure their individual procurement and hedging strategies and what risk management approaches they employ to fulfil their supply obligations. To prepare the assessment, the necessary information is requested and recorded in a standardised manner, thereby establishing a robust basis for the assessment.

Based on the results of the risk assessment, the EU requires each Member State to draw up a plan setting out specific precautionary measures. To this end, the Federal Ministry for Economic Affairs and Energy (BMWE) publishes the **Gas Prevention Plan** for the Federal Republic of Germany (most recently in 2019).[28] It sets out preventive measures to enhance the security of supply of the gas network. In doing so, it relies on a combination of infrastructure development, market design and regulatory requirements to reduce risks at an early stage and prevent supply crises. It also addresses systemic requirements of the EU Gas SoS Regulation, such as the N-1 rule within the gas network, and aims to meet these requirements. Overall, the

Prevention Plan thus serves as a catalogue of measures aimed at enhancing the structural resilience of the gas system.

This security architecture is supplemented by the **Natural Gas Emergency Plan** for the Federal Republic of Germany, which was last updated by the BMWE in 2023.[29] In the event that preventive measures prove insufficient, this plan sets out the **operational crisis management framework** for the gas sector at national level: it defines roles and responsibilities as well as measures to be taken in the event of a crisis.

In summary, the **gas sector's resilience system** comprises risk assessment, prevention and emergency measures. With regard to the levels of action covered in the gas sector, **operational measures** (emergency plan) are particularly evident here; however, these are supplemented by strategic considerations and thus include approaches to strategic resilience planning that can be further developed. In this regard, national implementation complies with the **requirements of the EU Directive** but does not go beyond them.

Energy reserves in Germany

The role of **strategic reserves** in Germany has grown in recent years due to the energy crises. Furthermore, Germany has also responded to **European regulations** in this regard.

Until 2022, Germany had no strategic gas reserve. In response to the EU's Gas SoS Regulation and the gas supply crisis caused by the war in Ukraine, the so-called '**Gas Storage Act**' – an amendment to the Energy Industry Act (EnWG) – was passed on 30 April 2022. It sets out binding **storage level targets**, which can, however, be flexibly adjusted by the Ministry in consultation with the EU, as was most recently seen with the reduction in storage level targets on 30 March 2025.[30] With a storage capacity of around 24 billion cubic metres, Germany theoretically has the largest natural gas storage capacity in the EU. This volume would be sufficient to supply Germany for two to three winter months of average cold.[31]

The **Petroleum Stockpiling Act** (ErdölBevG) regulates strategic stockpiling via the Petroleum Stockpiling Association (EBV) in order to mitigate short-term supply disruptions. The EBV is legally obliged to maintain stocks equivalent to at least 90 days' net oil imports in order to comply with EU Directive 2009/119/EC.[32]

There are also national provisions regarding **reserve capacities in the electricity market**. The Energy Industry Act (EnWG) enshrines in law the grid reserve (Paragraph 13d), the capacity reserve (Paragraph 13e) and the standby capacity for lignite-fired power stations (Paragraph 13g). Accordingly, transmission system operators are obliged to maintain appropriate reserve capacities and to procure them through tendering procedures; the Federal Network Agency (BNetzA) exercises regulatory oversight in this regard.

In summary, German energy policy in the area of resilience therefore tends to respond to European regulations after the fact. However, the **proactive design** of **measures based on resilience criteria** that go beyond European rules remains **patchy**, particularly when compared with the European best-practice approaches presented in this study. The strategic planning approaches described for the electricity grid are lacking in other areas of the German energy sector.

3.3 Conclusion: Fragmentation and gaps

The analysis of European and German resilience structures in the energy sector paints a **mixed picture**: whilst robust instruments for crisis prevention and reactive crisis management exist at the **operational level** – such as the Risk Preparedness Regulation, the national risk prevention plans, the Natural Gas Emergency Plan and the KRITIS regime – **strategic resilience planning exhibits gaps.**

In the energy sector, the European framework sets important **minimum standards** through the RPP obligation, the CER Directive and the EU Gas SoS Regulation, and creates incentives for resilience policy through the European Commission's benchmarking approach. Nevertheless, the focus of these instruments remains predominantly operational: they regulate roles, responsibilities and response mechanisms in the event of a crisis, but only marginally influence forward-looking, structural energy system planning.

Through the German Risk Prevention Plan and the Natural Gas Prevention and Emergency Plan, the BMWE implements the European requirements and, by incorporating national scenarios, develops approaches for **strategic resilience planning**. However, the analysis is carried out separately for the respective 'silos' of the gas and electricity networks and does not provide a comprehensive, strategically forward-looking view of the energy sector as a whole.

The European Commission's Strategic Foresight Report 2025, mentioned at the outset, demonstrates that existing gaps and, at the same time, the need for strategic resilience planning at European level have been recognised. At national level, too, there are further approaches to strategic resilience planning: the 'German Strategy for Strengthening Resilience to Disasters', published in 2022 by the then Federal Government, set out a cross-sectoral approach to society-wide and preventive disaster management.[33] The strategy places particular emphasis on the importance of forward-looking risk analyses and thus provides important impetus for strategic resilience planning. However, it remains at a high-level and does not contain any concrete implementation strategies focusing on the energy sector. In 2023, the then Federal Government published the "Roadmap for System Stability – A Roadmap for Achieving Safe and Robust Operation of the Future Electricity Supply System with 100 per cent Renewable Energy", outlining a strategic approach to integrating resilience criteria into **forward-looking electricity supply planning**.[34] The IEA's 2025 analysis refers to this and highlights the strategic opportunities that may lie in further decarbonisation.[35]

In summary, however, it can be noted that national **strategic resilience approaches**, beyond the measures required by European regulations or directives, are few and far between. The result at national level is a **fragmented resilience architecture** in which detailed operational planning and reactive crisis coordination are comparatively well developed, whilst comprehensive, forward-looking and criteria-based strategic resilience planning is lacking.

Particularly at a time of profound **structural change** in the energy system – characterised by decarbonisation, the expansion of renewable energies and increasing interconnection with European partners – strategic resilience planning offers great potential. This requires greater **integration of resilience criteria** into strategic energy planning, going beyond existing operational crisis management and taking the **entire energy system** into account.

4 INTERNATIONAL COUNTRY ANALYSES

4.1 Finland

Finland has the model of crisis preparedness in the energy sector that is most frequently cited as a benchmark internationally. A defining factor here is the country's particularly high **vulnerability in terms of security policy** due to the Soviet Union and Russia. Finland relies in particular on **public-private cooperation** between the state and the energy sector, which has developed over decades. The overarching concept of 'comprehensive security' (kokonaisturvallisuus) assigns a central role to energy supply, which is evident at all relevant levels. The key principle in the division of responsibilities is: 'The Ministry of Economic Affairs oversees energy security. The specific measures are implemented by companies in the sector.'[36] The National Emergency Supply Agency (NESA, Finnish: Huoltovarmuuskeskus) forms the key interface between the state and the private sector.[37]

It is important to note that Finland's resilience strategy is based on a framework that differs significantly from that of Germany. Finland's **electricity system is almost entirely CO_2-free** and hardly dependent on imports: In 2024, around 39% of electricity generation came from nuclear power (with the new Olkiluoto 3 reactor being a key factor), 25% from wind power – which overtook hydropower as the second-largest source of generation for the first time in 2024 – as well as 17% from hydropower and around 13% from wood and biofuels. Overall, just over 95 per cent of electricity generation was CO_2-neutral, and 96 per cent of consumption was met by domestic generation.[38] Across all energy sources and in terms of total energy supply, Finland had a comparatively low dependence on imports of around 33 per cent in 2024.[39]

At 4.4 per cent, **natural gas** plays only a minor role in Finland's total energy consumption and is used primarily in the chemical and forestry industries.[40] Since Russian pipeline supplies via the Imatra entry point ceased in May 2022, natural gas has been supplied exclusively via the Floating Storage and Regasification Unit (FSRU) in the port of Inkoo, which has been in operation since early 2023 and can also supply Estonia and, potentially, the wider Baltic region via the Balticconnector pipeline. **Hard coal** has practically ceased to be used in Finnish power generation since the beginning of April 2025; the Finnish Coal Phase-out Act stipulates a binding ban on the use of hard coal for power generation with effect from 1 May 2029.[41] The only remaining coal-fired power station, Meri-Pori (565 MW), has been contractually reserved for crisis situations since 1 April 2024 (see below).

In addition to Finland's historically persistent security threats and its almost complete self-sufficiency in electricity generation, a third notable factor is its dependence on maritime infrastructure and, consequently, the need to pay particular attention to hybrid threats.

Finnish energy resilience is embedded in the **comprehensive security** model set out in the 'Security Strategy for Society' (*Yhteiskunnan turvallisuusstrategia*, YTS). The latest version was adopted on 16 January 2025 as a resolution of the Council of State and identifies 56 strategic tasks assigned to the ministries[42] . Accordingly, energy supply must be ensured through cooperation between public authorities, businesses, associations and the general public. Strategic oversight is provided by the **Security Committee** (*Turvallisuuskomitea*), which is based at the Ministry of Defence and develops national threat and risk scenarios on an inter-ministerial basis. On this basis, the individual ministries develop sector-specific precautionary measures.

In the energy sector, **political responsibility** lies with the Ministry of Economic Affairs and Employment (*Työ- ja elinkeinoministeriö*, TEM). It is responsible for energy policy, security of supply and the legal framework for regulated market sectors. At the operational level, the **National Security Supply Agency** (*Huoltovarmuuskeskus*, hereinafter **NESA**) is responsible for the operational coordination of crisis preparedness. NESA was established in 1993 under the Security of Supply Act (1390/1992) and operates as an agency under the TEM. Its core tasks include building up and maintaining state reserves, managing mandatory stockpiling by businesses, and organising cooperation with the private sector. In the electricity sector, the transmission system operator **Fingrid Oyj** acts as a key player; the Finnish state holds a majority stake in the company via NESA and through direct ownership. The Energy Authority (*Energiavirasto*) is responsible for regulatory oversight and reviews the legally required contingency plans of the network operators.

4.1.1 Institutional Framework & Cooperation Structures

A characteristic feature of the Finnish model is the use of so-called **sectors and pools**. These bring together the companies, associations, authorities and the armed forces relevant to the respective supply sectors to form permanent cooperation structures. In the energy sector, the energy supply sector (comprising the **electricity and district heating pool, the oil pool and the gas pool**)[43] is particularly relevant. Participation by companies is, in principle, voluntary and does not involve any membership fees. The pools serve to facilitate the exchange of information, the joint simulation of crisis scenarios and the preparatory planning of measures for disruptions and emergencies. NESA selects participants based on their relevance to the supply chain.

In a conversation with a Finnish government official (TEM), this public-private partnership was described as the ‘crown jewel’ of the Finnish approach. It works, the official explained, because it has been built up over decades and has established a **relationship of trust between the state and businesses**. At the same time, the official identified a clear point of friction: the voluntary nature of the scheme works well at the organisational and informational levels. However, as soon as **investment** in preparedness capacity becomes necessary, a **funding problem** arises in the competitive sector that cannot be resolved without legislative requirements or guaranteed refinancing. This finding is central to the German debate: transferring the pools without clarifying the financing of investment would fail to replicate the key strength of the Finnish model – the binding nature of the arrangements, which go beyond statutory obligations.

When assessing the transferability of the model to the German context, it must be borne in mind that the basic elements of public-private cooperation already exist in **Germany** – through **industry associations**, **KRITIS working groups** and **sectoral crisis management teams**. Against this background, establishing an additional institutional framework based on the Finnish model would only make sense if it generated clear added value compared with the existing structures.

Nevertheless, three aspects argue in favour of examining the Finnish approach more closely: Firstly, the pool structure creates a ‘level playing field’ between large suppliers and local authorities, which would have particular significance within the German federal system. Secondly, it would make the **coexistence –** deliberately established in Finland – **of voluntary cooperation in the competitive sector and statutory obligations in the monopoly sector** visible in Germany as well, and would define the institutional **interfaces for a resilience policy** more clearly. Thirdly, a comparable structure would address the issue of equal treatment in network operation – which arises with every special provision in Germany – in accordance with an established model. However, the legal feasibility, particularly in relation to the EU State aid framework and the principle of non-discrimination in network regulation, must be assessed on a case-by-case basis.

4.1.2 Scenarios & Planning Tools

Finnish resilience planning is based on a three-tiered **scenario system** that is deliberately not **structured in** a fully **hierarchical manner**. At national level, the Security Committee, in collaboration with the ministries, draws up the national risk assessment (*Kansallinen riskiarvio*)[44] and defines the overarching threat framework, most recently in 2023. At sectoral level, the Energy Authority (*Energiavirasto)* draws up the **formal prevention and risk preparedness plans**[45] based on EU Regulations 2017/1938 (gas) and 2019/941 (electricity). At the operational level, NESA coordinates corporate preparedness with the sectors and pools and finalises the stockpiling and exercise scenarios.

The overarching principle of Finnish scenario design was succinctly formulated during an expert discussion with a Finnish government official: one must be prepared “for everything that is relevant”. Politically, this means a **conscious decision not to commit to specific scenarios**; rather, the technical risk analysis is intended to define the situations requiring coverage. This ‘open list’ differs fundamentally from German practice, where the gas prevention plan to date covers only the three EU standard scenarios and does not specify **any geopolitically driven disruption scenarios** as a binding basis for planning. The Finnish government official also acknowledged that the interlinking of the three scenario levels is not fully formalised even within Finland. The Security Committee’s strategic guidelines are not legally binding, but in practice they guide sectoral preparedness work.

It is particularly important to note that these scenarios do not remain abstract, but are incorporated into technical network planning. Regulated network operators (both TSOs and DSOs) are subject to statutory contingency planning obligations, the specific requirements of which are laid down in legislation by the TEM and which *Energiavirasto* assesses on the basis of the network operators’ respective contingency plans. These obligations explicitly include preparation for situations that would fall under the *Emergency Powers*

Act, i.e. exceptional and crisis scenarios beyond normal operations. However, according to the Finnish government official, a debate on reform is also underway in this area: whether the current legal framework covers all relevant scenarios – in particular, whether it allows network operators to implement **their own stockpiling measures** – is the subject of an **ongoing review within the ministry**.

Finnish scenario planning is also shaped by two recent events: the damage to **the Balticconnector** in October 2023[46] , which cut Finland off from its sole gas pipeline supply and immediately exposed the vulnerability of maritime infrastructure in the Baltic Sea, and the lessons learnt from the war in Ukraine. From the latter, Finnish resilience planning explicitly concludes that a **concentration of the generation fleet on a few large units** and a centralised transmission grid represent the greatest vulnerability. Unlike the discussions in Germany, security of supply is not addressed through the introduction of a capacity market – there is no such market in Finland. Finland combines an 'energy-only' market with a statutory peak load reserve managed by Fingrid (currently without contracted capacity) and manages distributed capacity via distribution network requirements and the Non-Fossil Flexibility Support Scheme, which is currently being prepared.

For the German context, a possible starting point can be derived from the Finnish approach: a competent authority draws up a technically justified, regularly updated list of scenarios relevant to contingency planning, publishes it and makes it the basis for abstract **contingency obligations** for grid operators and – within the framework of legally permissible incentive instruments – also for generators. This approach could relieve the political level of the need to present a comprehensive threat analysis ex ante.

4.1.3 Strategic Reserves & Stockpiling

In the area of stockpiling, Finland follows a two-pillar model. The first pillar consists of **state reserves**, which NESA maintains for key fuels and energy sources. The second pillar comprises **statutory stockpiling obligations for importers**, who, whilst holding legal title to these stocks, cannot freely dispose of them in the event of a crisis. The exact quantities and storage locations of the state reserves are subject to confidentiality. According to a Finnish government official, the state reserves, together with the mandatory corporate stocks, cover **approximately five months' consumption** and thus significantly exceed the European minimum quotas (see above).

The stocks consist of oil, hard coal and – where no direct storage facilities are available – substitute fuels for natural gas. Finland does not have its own underground gas storage infrastructure. The Finnish government official describes the role of stockpiling pragmatically: those who import must stockpile; those who do not import don't need to stockpile. The Finnish approach is therefore not at odds with decarbonisation, but is **structurally linked to the country's dependence on imports**.

One measure of particular conceptual relevance, beyond the mere stockpiling of fuel, is the explicit designation of a **power station for use in crisis situations**. On 30 October 2023, NESA and the operator Fortum agreed to reserve the generation capacity of **the Meri-Pori hard coal-fired power station** (565 MW) for serious disruptions and crises from 1 April 2024 to 31 December 2026[47] . This is therefore explicitly a state-guaranteed generation reserve that no longer participates in market operations.

This raises two points of reference for the German debate. Firstly, the Finnish approach suggests that a cross-fuel stockpiling strategy – similar to that in Poland (see below), but with a clearer integration of state and corporate stocks – would also be suitable in Germany to expand stockpiling, which is currently only legally guaranteed for oil. The **good storability of hard coal** remains a distinct advantage in this regard.

Secondly, whilst Germany already has three reserve mechanisms, Meri-Pori differs from all three in a way that is directly relevant to the German debate on resilience. The **security reserve** under the KVBG was a climate policy transition instrument with a fixed term. It was not designed as a long-term resilience instrument. The **grid reserve** under the Energy Industry Act (EnWG) is linked to system relevance for grid operation and is triggered by the transmission system operators under the supervision of the Federal Network Agency. It is intended for use in the event of bottlenecks and redispatch situations, not crisis scenarios. The **capacity reserve,** for its part, addresses rare market-related shortages through a market- and grid-operational approach. What all three instruments have in common is that they were **not designed with civil crisis preparedness in mind**, but rather from the perspectives of market, grid or climate policy.

There is currently no equivalent in Germany to the explicitly civil protection and resilience-driven **safeguarding of an existing power station by a preparedness agency**. The institutional placement of such a function in Germany could be examined – for example, within the Federal Office for Civil Protection and Disaster Assistance (BBK) in consultation with the Federal Ministry for Economic Affairs and Energy (BMWE), or within a newly established body. In any case, the Finnish model demonstrates that such a form of reserve can be implemented in practice within the existing EU framework.

4.1.4 Network and System Architecture

A key insight from the expert discussion concerns the **strategic prioritisation of decentralised generation**. Based on observations of Russia's actions against Ukraine's electricity supply – initially attacks on the transmission grid, then centralised generation, and increasingly also flexible generation and distribution networks – Finnish planning concludes that large power stations and the high-voltage grid represent the greatest systemic vulnerability. The response to this is a targeted promotion of distributed generation, with the Finnish government official identifying **connection at the distribution network level** as **a pragmatic threshold**: anything connected at the distribution network level is considered decentralised. Anything connected to the transmission grid is "already a major target".

The urgency of decentralisation in Finland is further heightened by the **highly concentrated** nature of **the country's nuclear power capacity** – the Olkiluoto 3 reactor, with a capacity of 1,600 MW, has been in commercial operation since April 2023, and nuclear power stations are operated at just two sites (with five reactors). Although nuclear power thus contributes significantly to domestic electricity generation (39 per cent), it exhibits pronounced single-point-of-failure characteristics, which must be systematically offset by decentralised generation.

It is noteworthy that Finland does **not primarily** achieve decentralisation **by subsidising distributed generation facilities**, but rather through three indirect yet far-reaching mechanisms which, when combined, lead to a structurally more decentralised generation system.

The first mechanism is a **performance-based regulatory requirement in the distribution network**. The *Sähkömarkkinalaki* (Electricity Market Act, 588/2013) obliges Finnish distribution system operators to plan, construct and operate their networks in such a way that a **supply interruption** at a connection point lasts no longer than six hours in urban areas and no longer than 36 hours in other areas. Full compliance with this requirement is to be implemented in stages; the original deadline of 31 December 2028 was extended to 31 December 2036 by Amendment 730/2021[48] for distribution system operators with a proportion of underground medium-voltage lines of 60 per cent or less. For these network operators, an interim target of 75 per cent of connections by the end of 2028 applies.

This requirement is accompanied by a **statutory obligation for distribution system operators to pay compensation**, which applies automatically in the event of outages lasting twelve hours or more and increases as the duration of the outage lengthens. Payment to electricity customers is made automatically via the network usage bill – the customer does not need to take any action. The basis for calculation is the annual network usage charge, graded according to duration. The regulation leaves it up to the more than 70 distribution system operators to decide whether to achieve resilience through, for example, underground cabling, additional grid redundancy, emergency generators, enhanced integration of local generation, or combinations thereof.

In practice, **underground cabling at the medium-voltage level** predominates, supplemented by **local resilience solutions**. At lower voltage levels, particularly in rural supply areas, the outcome often favours decentralised and local components. The mechanism is clearly formulated in regulatory terms, technology-neutral and conducive to decentralisation, without explicitly mandating decentralisation. At the same time, the scope of this approach is limited by the recent reform debate: the significant **increases in grid access charges** triggered by the legislation from the mid-2010s onwards have sparked an intense political debate in Finland about the costs of resilience and led to deadline extensions for some grid operators.

The second mechanism is the **structurally decentralised generation architecture** comprising combined heat and power (CHP) and district heating. In Finland, most towns and cities are supplied via district heating networks, with the heat predominantly generated in local CHP plants. These CHP plants, which are generally fuelled by wood (now mainly from Finland, though until 2022 there were high levels of imports from Russia), also contribute significantly to decentralised electricity generation. In 2024, 6.4 per cent of Finland's electricity generation came from CHP in district heating and a further 7.9 per cent from industrial CHP, with a peak load capacity of around 3,000 MW installed in district heating CHP. A characteristic feature is that district heating networks are typically supplied by several plants, have their own **reserve capacity and** are **multi-fuel capable**, thereby forming, by their very nature, a redundant supply structure that is spatially intertwined with the consumption load. From a resilience perspective, this constitutes a decentralised generation portfolio that has developed over decades, whose resilience benefits existed even before any explicit policy decision was taken and which is now systematically recognised as a key component.

The third mechanism is the integration of this architecture with an explicit prioritisation and restoration system. Under the Electricity Market Act, network operators are required to draw up contingency plans setting out the order of restoration following incidents. A government regulation[49] specifies that network operators must classify critical electricity consumers separately and categorise other consumers into at least three **priority categories**. This ensures that the restoration of supply following disruptions takes place in accordance with verifiable criteria.

4.1.5 Conclusion: Possible Courses of Action for Germany

In the **German context**, several potential points of reference emerge which could serve as starting points for discussion on the further development of the German energy resilience framework.

Firstly, a results-oriented outage limit could also be discussed in Germany. German regulation includes quality indicators such as the SAIDI metrics, but no clear statutory upper limits on the duration of supply interruptions at the end-customer level. Adopting an outage limit modelled on the Finnish approach – differentiated by supply area type and with adequate lead time – would be a **far-reaching, technology-neutral lever that indirectly enhances the value of decentralised solutions** and could therefore be examined.

Secondly, the Finnish experience highlights the resilience value of a combined heat and power (CHP) and district heating infrastructure. With its municipal utility and district heating structure, Germany has a fundamentally comparable starting point; the continued operation and expansion **of local CHP and district heating generation** should therefore **be assessed** in the context of resilience not only from a climate policy perspective, but also explicitly **from a precautionary standpoint**. Thirdly, the Finnish practice of officially binding load prioritisation offers a possible reference model for a comparable regulation in Germany.

In addition – without overstretching the argument – it should be noted that the German discussion regarding a **'resilience factor'** in the **Power Station Strategy** and in the forthcoming tenders would constitute an independent extension of the approach. It would complement the Finnish approach with a market- and procurement-based control mechanism. Such a factor could potentially be operationalised via a manageable scale that takes into account the connection level (distribution network vs. transmission network), geographical distribution and the ability to operate in island mode. However, there is no Finnish model for such a **quantified resilience indicator as a formal tender criterion** – this would therefore represent a genuinely German further development.

Finally, mention should be made of the close regional cooperation between the Nordic transmission system operators, ministries and emergency preparedness agencies within **the NordBER Forum**, which has for decades provided a platform for joint preparedness and stockpiling issues. This form of sub-regional resilience cooperation at a level above the EU offers a model for deeper cooperation between Germany and its neighbours – particularly regarding how interconnectors and shared reserve infrastructure can be safeguarded through bilateral and multilateral agreements without weakening the single market. Measures based on this approach in the German context would first need to be examined and discussed with the TSOs and the relevant authorities.

4.2 Sweden

Sweden demonstrates strong evidence of the integration of resilience factors into the energy sector in several areas. This is particularly evident when considering the **institutional embedding** of resilience through the national concept of **'total defence'** (totalförsvar), and specific requirements such as the population's **one-week self-sufficiency**, the Styrel prioritisation system for manual **load shedding,** and systematically developed **off-grid operating capabilities** (ödrift).

Sweden pursues a **sectoral approach that is centralised in many areas**: responsibilities remain with the specialist authorities, which combine both operational and regulatory functions. With its **accession to NATO** in March 2024[50] and the **Total Defence Decision** 2025–2030[51] , Sweden has significantly strengthened civil crisis preparedness in the energy sector. Against this backdrop, the Swedish model offers several points of reference for the German debate, without being directly transferable – particularly as the starting point (population density, generation mix, dependence on imports) differs significantly.

Sweden's electricity system is **almost entirely CO_2-free**. In 2024, around 38% of electricity generation came from hydropower, 29% from nuclear power and 23% from wind power, with the remainder coming from biomass, solar and small amounts of fossil fuels.[52] Sweden is a net electricity exporter. Across all energy sources and in terms of total energy supply, Sweden showed a comparatively low import dependency of around 27% in 2024.[53] Natural gas plays a very minor role in primary energy consumption (around 2%); the gas supply is concentrated in the south-west and is entirely dependent on imports. By contrast, oil continues to dominate final energy consumption in the transport sector and is entirely imported. The resilience strategy therefore focuses heavily on the **electricity system** and on the issue of restoration and stabilisation in the event of a crisis, rather than on the diversification of fuel import routes.

The key strengths lie in the **institutional consolidation** of operational and regulatory responsibilities within the specialist authorities, in the politically enshrined **prioritisation of civil** crisis preparedness within the framework of the comprehensive defence concept, and in a range of operationalised **resilience instruments**.

4.2.1 Institutional Framework & Cooperation Structures

The institutional framework for energy resilience in Sweden is clearly divided: the **key specialist authorities** in the energy sector combine operational tasks with regulatory and crisis preparedness responsibilities, supplemented by an inter-ministerial **coordination structure** led by the Government Offices (Regeringskansliet) and the Ministry of Defence (Försvarsdepartementet).

The **Swedish Energy Agency** (Statens energimyndighet, or Energimyndigheten for short) has overall **sectoral responsibility** for civil contingency planning in the energy sector (sektorsansvar). This responsibility covers electricity, district heating, energy gases and fuels.[54] Energimyndigheten is also responsible for drawing up the **national risk preparedness plan** for the electricity sector (RPP) in accordance with the EU Regulation, coordinates the national emergency oil reserves in line with IEA commitments and the EU Directive, and is the competent authority for the implementation of NIS 2 in the energy sector. As part of Sweden's NATO membership, Energimyndigheten also represents Sweden in the **Energy Planning Group of the NATO Resilience Committee**.[55]

Dual role as transmission system operator and electricity emergency authority

A striking institutional feature of Sweden is the combination of operational system responsibility and regulatory powers under a single body: the Swedish state-owned company **Svenska Kraftnät** is not only the transmission system operator for the Stamnät (the Swedish 220/400 kV extra-high-voltage grid), but also the state electricity emergency authority.[56] This dual role has been firmly institutionalised under the Swedish Electricity Emergency Act for almost 30 years.[57]

Svenska Kraftnät thus operates in three interrelated roles, which were particularly highlighted in the expert discussion[58] : firstly, the operational **management of the transmission grid,** including frequency and voltage control; secondly, **regulatory powers to set binding requirements** for electricity system operators (e.g. regarding risk and vulnerability analyses or the stockpiling of spare parts); thirdly, the provision of **services to the approximately 170 Swedish distribution system operators**, including training, exercises, material coordination and co-financing of investments in resilience measures.

During the expert discussion, it was also emphasised that this institutional structure is highly effective because **regulatory requirements** can be **directly linked to funding mechanisms**. Specifically, Svenska Kraftnät can, for example, stipulate that all network operators must hold certain spare parts in stock, whilst at the same time providing funds to co-finance these investments. In Germany, these functions are divided amongst four transmission system operators, the Federal Network Agency, the Federal Ministry for Economic Affairs and Energy (BMWE) and security authorities.

Crisis coordination and cross-sectoral cooperation

At the level of inter-ministerial crisis preparedness, Sweden's institutional architecture has been reorganised in recent years. The former Myndigheten för samhällsskydd och beredskap (MSB) was renamed at the start of 2026: the new Myndigheten för civilt försvar (MCF, **Civil Defence Agency**) took over the responsibilities for civil defence and crisis preparedness.[59] The security situation is divided into twelve crisis preparedness sectors (preparedness sectors, beredskapssektorer).[60] The energy supply sector (Energiförsörjning) is managed by the Energy Agency (Energimyndigheten). A further level is formed by the six major civil areas (civilområden), each of which, under the leadership of a Länsstyrelse (county administrative board), acts as a coordinating body between the national and local levels. During the expert discussion, it was emphasised that, from a historical perspective, this system has developed in a rather decentralised and informal manner. It produces diverse and tailored solutions, but can also lead to duplication of effort and complicate national coordination.

4.2.2 Scenarios & Planning Tools

In Sweden, resilience in the energy sector is strategically anchored through the concept of total defence. A characteristic feature that stands out in international comparison is the approach of treating military and civil defence as an integrated whole. With the **Total Defence Decision** 2025–2030, the Swedish Parliament has approved what is arguably the most comprehensive modernisation of Sweden's security architecture since the end of the Cold War.

The total budget amounts to around **SEK 170 billion** (just under EUR 16 billion) for military defence and **SEK 37.5 billion (around EUR 3.5 billion) for civil defence by 2030**. In the area of civil crisis preparedness, energy supply, transport, food and drinking water supply, and healthcare are among the sectors explicitly prioritised. In the energy sector, the resolution specifically sets out the expansion of the electricity grid, repair capacities (equipment and personnel), the ability to operate in island mode, and the physical protection of critical infrastructure. In addition, there are commissions to examine the introduction of compulsory civilian service (civilplikt) in the electricity sector. Svenska Kraftnät has been tasked with submitting a proposal by February 2027 to strengthen the security of grid operations.[61]

Central to, and characteristic of, Sweden's approach is the target that the population should be able to cope for at least **one week without state support** (the so-called 'En vecka' recommendation, formerly 72 hours). This requirement was widely publicised in the 2024 brochure 'Om krisen eller kriget kommer'[62] ('If a crisis or war were to occur'), which was distributed to all Swedish households. This provides a **direct guideline for crisis preparedness** at both the local authority and individual levels, and thus also sets out specific **requirements for energy supply** – for example, for hospitals, water supply and heating. However, during the expert discussion, it was noted with some reservation that, in practice, meeting this requirement depends heavily on local commitment and the availability of at least co-financed investments; the formal requirement alone is not sufficient.

Scenario portfolio lacks coherence

The risk assessment is largely supported by the **Swedish Defence Research Agency** (Totalförsvarets forskningsinstitut, FOI), which reports to the Ministry of Defence.[63] The FOI develops scenarios, methodologies and threat analyses for, amongst others, the Swedish Energy Agency (Energimyndigheten), Svenska Kraftnät, the Civil Contingencies Agency (MCF) and the Ministry of Defence.

During the expert discussion, it was emphasised that whilst the FOI scenarios are used regularly, **they do not constitute an officially binding national scenario portfolio**. Unlike the United Kingdom, for example, Sweden does not publish a coherent list of prioritised stress scenarios for energy network planning. Instead, stakeholders at national, regional and local levels each use their own criteria or scenario frameworks drawn from the FOI portfolio. According to the expert discussion, this rather informal approach to scenario planning corresponds to Sweden's historically developed, decentralised crisis preparedness system.

Integration into the network development planning still in progress

A key instrument for integrating resilience into planning processes is the obligation, in place for over ten years, for all electricity system operators to carry out **an annual Risk and Vulnerability Analysis** (RSA) and submit it to the relevant authorities (Svenska Kraftnät or the Energy Market Inspectorate, Energimarknadsinspektionen).[64] The RSA requirement is enshrined in the Electricity Emergency Act (elberedskapslagen 1997:288) and set out in detail in Svenska Kraftnät's regulations (SvKFS).

The **methodological approach** is standardised by joint guidelines issued by Svenska Kraftnät and the industry association **Energiföretagen Sverige**. During the expert discussion, it was emphasised that the RSA requirement has, over the years, established a significant risk culture within the industry, although the focus has traditionally been on storms, frost and technical failures, and needs to be adapted to the new geopolitical challenges. Consequently, systematic implementation has not yet taken place.

In the latest Swedish **grid development plan** (extra-high-voltage grid), published at the end of 2025, Svenska Kraftnät emphasises that, whilst the systematic incorporation of resilience criteria into long-term grid planning is necessary and has been decided at a political level, it is currently still a work in progress: "As the defence resolution clearly stipulates that Svenska Kraftnät must align its operations with the requirements of wartime, work is currently underway to ensure that our principles and criteria for regular, long-term grid planning support this alignment. In the long term, this will result in an electricity system with greater capacity," states the Swedish NEP.[65]

Accordingly, **resilience investments** in electricity grid planning will not yet be managed via a formal **'resilience' investment pathway integrated** into the grid development plan, but rather through separate, application-based 'Beredskapsåtgärder' (crisis preparedness measures) at Svenska Kraftnät. Distribution system operators can submit targeted applications for co-financing for investments that enhance resilience (e.g. reserve generators, spare transformers, reserve transformers, island operation equipment). In the expert discussion, this was described as operationally effective but, in some respects, circular: Svenska Kraftnät can impose a reserve obligation and, the following day, make funds available to fulfil this obligation. The effectiveness therefore depends heavily on the funding allocated to the emergency preparedness measures.

4.2.3 Strategic Reserves & Stockpiling

Sweden combines a market-based **strategic reserve** (*strategisk reserv*) with a government-mandated **Elberedskap reserve**. Since 15 March 2025, the strategic reserve has replaced the expired effektreserv. It is active seasonally (16 November to 15 March) and is contracted by Svenska Kraftnät through tenders; in the winter of 2025/2026, it amounted to 350 MW – after the original tender for up to 800 MW in October 2025 had initially failed due to excessively high bids. The previous volume stood at 562 MW. Under the new regulatory framework, multi-year contracts are now only permitted for fully fossil-free plants.

This is to be distinguished from the **statutorily mandated reserve** based on the Elberedskapslagen[66] . The most prominent example is the Öresundsverket power station (Uniper, 448 MW natural gas combined cycle) near Malmö, which was decommissioned in 2016 due to uneconomic operation and which Svenska kraftnät, in its capacity as the Elberedskapsmyndighet, ordered to be recommissioned in June 2023. The plant was restarted for the first time on 17 January 2025 and officially placed on standby on 5 May 2025.

In **Germany**, **this distinction** has **not been fully implemented**. Section 13c of the Energy Industry Act (EnWG) (grid reserve) relates to the grid, Section 13e of the Energy Industry Act (EnWG) (capacity reserve) relates to the market, and the security standby requirement (KVBG) is motivated by climate policy – there is no dedicated reserve regime based on resilience or civil protection with its own legal basis. The ongoing debate on power station strategy is also primarily focused on the market and security of supply, rather than being based on resilience.

4.2.4 Network and System Architecture

The systematic preparation of **island operation capabilities** (*ödrift*) is linked to Elberedskap and, in particular, the Öresundsverket. Svenska Kraftnät has divided the country into electricity supply zones[67], the generation and consumption balances of which are analysed with a view to emergency operation. Among other things, the analysis examines the facilities required for black start, regional self-sufficiency and interaction with the transmission grid. Sweden has carried out relevant exercises in several regions in recent years, including in Malmö. During the expert discussion, it was noted that, during island operation, local generation is regularly insufficient to cover the full load; accordingly, integration with the 'Styrel' prioritisation system, described below, is central.

By way of comparison, in **Germany**: black start capability is also enshrined in regulation, but is organised in a decentralised and market-based manner. In accordance with Paragraph 13 of the Energy Industry Act (EnWG), each of the four transmission system operators bears system responsibility within its respective control area. The procurement of the non-frequency-related system service 'black start capability' takes place via public tenders in accordance with Paragraph 12h of the EnWG and the provisions of the Federal

Network Agency. This is supported by TSO-specific grid restoration plans in accordance with the EU Network Code (Regulation (EU) 2017/2196).

The Styrel prioritisation system ("Styrning av el till prioriterade användare") is a planning procedure regulated in the Styrel Regulation (in accordance with EU Directive 2019/941[68]) and in the regulations of the Swedish Energy Agency, designed to ensure that, in the event of a manual load shedding, socially critical electricity consumers (e.g. hospitals, waterworks, the police, broadcasting, selected industrial facilities) are given priority supply. **Identification and prioritisation take place from the bottom up**: local authorities, in collaboration with the Länsstyrelser (roughly equivalent to district authorities), identify the consumers that are critical to them. The Länsstyrelser consolidate this information at regional level; the distribution system operators translate the prioritisation into operational load shedding plans; and at national level, Svenska Kraftnät coordinates the load shedding.

The grey area between market and crisis operations

If Svenska Kraftnät orders a load shedding, the network operators must implement the required load reduction within 15 minutes.[69] Styrel was originally introduced in the 1970s in response to the oil crisis and has been further developed several times since then. In the expert discussion, 'Styrel' was identified as **one of the key foundations for resilient crisis management**, although research has highlighted that 'Styrel' has not yet been fully integrated into the overarching crisis management system and that there is room for improvement in cooperation between public and private actors.

One aspect discussed at length in the expert discussion – and one that is increasingly being addressed in Swedish research – is the regulatory gap between a purely market-based state of peace and a state-controlled emergency or wartime operation. Sweden – like most European states – has **no established rules for a 'grey zone'** of protracted hybrid or economic warfare, in which market mechanisms and crisis mechanisms must operate in parallel. This is relevant insofar as investment decisions, bottleneck management and procurement strategies of market actors are potentially distorted by the uncertain triggering of state interventions (e.g. the mobilisation of strategic reserves, interventions in price formation). This issue of interface is also relevant to the German resilience debate, as Germany exhibits structurally similar gaps.

4.2.5 Conclusion: Possible Courses of Action for Germany

Despite the differences in the starting points, several points of reference relevant to Germany can be derived from the Swedish model, which can serve as starting points for discussion on the further development of the German energy resilience framework:

Firstly, the **consolidation of operational and regulatory responsibilities within Svenska Kraftnät** demonstrates how technical crisis preparedness can be organised under a single authority. This institutional consolidation can be regarded as a measure that significantly enhances resilience. However, it is not directly transferable to Germany. The question remains as to where a comparable function would need to be located in Germany (**the Federal Ministry for Economic Affairs and Energy, the Federal Chancellery or the Federal Network Agency**). The Swedish experience shows that such consolidation within a specialist agency embedded within a ministry and with a triple mandate (operation, regulation and financing decisions) can be operationally effective without the need for strategic oversight to be placed at a particularly high political level.

Secondly, the call for self-sufficiency over several days provides a concrete, relevant benchmark for the German debate on municipal crisis preparedness. It translates the abstract goal of resilience into operational requirements for energy suppliers, hospitals, drinking water supply and heating provision, without delving into the logic and costs of complete energy self-sufficiency. When applying this to the German context, however, it should be noted that the responsibilities, technical requirements and cost-sharing arrangements for the measure have not yet been defined and would first need to be discussed.

Thirdly, Styrel presents a model that lends itself to a bottom-up prioritisation system, which has been assessed by technical experts as highly relevant. Its transferability depends on whether a comparable prioritisation system is enshrined in Germany as part of the national energy strategy or as a separate legal instrument; given the risks of legal action, enshrining it separately may be advisable.

Fourthly, the Swedish example of island operation capabilities illustrates how regional resilience can be operationalised in technical, organisational and planning terms without abandoning the European single market. In expert discussions in Germany, island operation was classified as technically feasible but not a mandatory priority. However, in conjunction with Styrel and targeted emergency power facilities (such as the Öresundsverket), an operationally effective system emerges comprising an emergency power plant, load prioritisation and regional supply capability.

Fifthly, with regard to strategic planning documents, it should be noted that, despite its total defence concept, the Swedish model also lacks a coherent, binding national scenario architecture for energy grid planning. The separation between FOI scenarios (research), crisis preparedness plans (operational authorities) and grid development planning (Svenska Kraftnät) demonstrates that the consistent integration of stress scenarios into grid planning is not a given, even within a mature resilience system.

4.3 Japan

Japan, as the world's fourth-largest economy, Asia's second-largest and a liberal parliamentary democracy, offers valuable insights into issues of strategic resilience planning outside the EU, particularly regarding fuel and energy stockpiling. The close relationship between the private and public sectors, along with the related issues of institutional anchoring and social acceptance, can provide important impetus for the German context.

Due to its extremely **high dependence on imports**, Japan is forced to keep a close eye on the issue of energy supply (energy self-sufficiency rate of approximately 15 per cent).[70] Russia's invasion of Ukraine in 2022, as well as escalating tensions in the Middle East (90 per cent of Japan's crude oil imports and a proportion of its LNG pass through the Strait of Hormuz)[71], have led – and continue to lead – to sharply rising energy prices and supply uncertainties, and highlight the vulnerability of Japan's energy supply to crises.

Japan's primary energy consumption is **dominated by fossil fuels**. Oil, LNG (Japan is the world's second-largest importer) and coal account for around 85 per cent, whilst almost 70 per cent of electricity generation in Japan is fossil-fuel-based.[72] However, renewable energies are to be expanded under a national 'GX Strategy'.[73] The *Great East Japan Earthquake* and the accident at the *Fukushima Daiichi Nuclear Power Station* in 2011 also exposed the physical vulnerability of the energy system, led to various institutional adjustments and contributed to a reduction in the share of nuclear energy in the electricity mix.[74] During the expert discussion, it was emphasised that in recent years Japan's political focus has broadened from a concentration on traditional fuel security to a **broader concept of system resilience**.

The analysis of the situation in Japan is particularly illuminating with regard to **stockpiling and reserve strategies** and their implementation, as well as the **organisation of cooperation between the state and businesses** under an inter-ministerial **resilience strategy**. This highlights some **key strengths** of the resilience approach adopted there.

4.3.1 Institutional Framework & Cooperation Structures

A distinctive feature of Japan is the close **cooperation between the public and private sectors**, which affords the executive branch extensive scope for steering energy strategy issues. As a result, the executive branch has a comparatively **high degree of steering authority**.

The **highest level of political governance** regarding energy policy and security in Japan is the **Ministry of Economy, Trade and Industry (METI)**. The Ministry sets out the general strategy in the form of regular strategy papers and related framework-setting administrative acts. The Ministry is responsible for energy security (supply and operations) and infrastructure; it defines Japan's energy strategy in the regularly published **Strategic Energy Plan (SEP)** and thereby establishes the framework for energy policy. The **Agency for Natural Resources and Energy (ANRE)** is an independent specialist agency within METI with its own budget, authority to issue directives and publishing apparatus. It implements energy policy at an operational level and bears primary responsibility for regulation, security of supply and resource policy. ANRE can compel market participants to comply with supply obligations. The gas sector also falls under ANRE's jurisdiction.

An institutionally organised partnership between the state and the energy sector

METI also oversees the state-run **Japan Organisation for Metals and Energy Security (JOGMEC),** a key authority for Japan's security of supply with considerable powers. JOGMEC is a **state-owned investment company** that utilises instruments such as direct equity investments and loan guarantees to support **private investment in security of supply both domestically and abroad**. In doing so, JOGMEC can directly counter-finance guarantees provided by individual energy companies for strategically important projects, thereby enabling these projects to secure financing on the capital market.

JOGMEC's main task is the **stockpiling** of oil, LPG and rare metals. To this end, JOGMEC organises and manages the state reserves and carries out or finances the construction of national **storage capacity**. JOGMEC's remit also includes managing investment in **the gas network** and – in the longer term – the establishment and development of a **hydrogen network**.

JOGMEC's remit also includes **strengthening supply chain resilience**. To this end, JOGMEC, amongst other things, annual surveys on LNG trade volumes and supply contract restrictions faced by Japanese companies, in order to determine the volumes imported.

Energy policy resilience as a component of foreign policy

JOGMEC is tasked with ensuring a stable supply of oil and gas and therefore has **'foreign policy' responsibilities** in the areas of exploration, development and production. This includes JOGMEC establishing its own relationships with resource-rich countries and procuring fuels when private companies are unable to do so. In this way, JOGMEC proactively addresses structural supply risks and can steer strategically sound investments. Given Germany's experience with one-sided energy dependencies, this institutional model could serve as an important **point of reference** for the structural further development of Germany's energy security framework.

One example is JOGMEC's involvement in the 'Scarborough gas project' in Australia in 2024.[75] The Scarborough project is an **offshore gas field off the coast of Western Australia**, whose natural gas is transported via a pipeline to the Pluto LNG plant, where it is processed into liquefied natural gas (LNG) for export to Japan, amongst other destinations. Through a combination of equity financing (up to 50 per cent of the project costs for 'LNG Japan') and comprehensive loan guarantees for Japanese investors (particularly for JERA), JOGMEC is facilitating the private sector's involvement in the Scarborough Gas Project. Specifically, JOGMEC reduces the financing risk for commercial banks through government guarantees, thereby making investment by Japanese companies feasible.

Energy policy resilience, with a view to safeguarding security of supply against geopolitical risks, is a **central component** of **Japanese foreign policy ('resource diplomacy')** and Japan's international relations.[76] In 2021, Japan therefore defined the securing of strategic advantages and the maintenance of the rules-based international order as strategic objectives, explicitly with a view to increasing the resilience of the national energy system. This demonstrates that issues relating to the resilience of the energy system are considered on a cross-ministerial basis.

Unlike in Germany, the issue of resilience is therefore also embedded at the level of the **'Cabinet Office'** (equivalent, in the German context, to the Federal Chancellery). As became clear during the expert discussion, the Cabinet Office is drawing up a cross-sectoral plan for national resilience, which also covers aspects such as civil protection. Furthermore, since 2021, the 'Council for the Promotion of Economic Security' has been established as an **interdepartmental cabinet body** that institutionally anchors resilience issues as a matter of national security.[77]

4.3.2 Scenarios & Planning Tools

In February 2025, METI and ANRE published the **seventh 'Strategic Energy Plan' (SEP)**.[78] The SEP sets the **guidelines** for all of Japan's energy policy regulation and investment. The private sector and local authorities align their own plans with it. As a result, the SEP has a **steering effect** that enables all stakeholders in the energy sector to focus more strongly on forward-looking resilience planning. Furthermore, Japan's **pragmatic approach** to expanding the energy system – prioritising renewable energies for resilience reasons – should be emphasised.

Scenario-based national energy strategy

The SEP is based on Japan's **overarching energy policy concept: 'S+E3**'. **S+E3** stands for ***Safety*** plus the three objectives ***of Energy Security*** (security of supply), ***Economic Efficiency*** and ***Environment*** (environmental and climate protection). Accordingly, energy supply is only acceptable if strict safety standards are met (the 'S' takes priority), and, building on this, the three 'E's are to be balanced simultaneously.

Resilience is a **cross-cutting issue** in the SEP, primarily intertwined with the areas of **security of supply** and **disaster management**. Consequently, resilience issues are primarily considered under the heading of preventative safety. The SEP sets out a binding framework for all downstream institutions, the private sector and local authorities. Import dependency, natural disasters and cyber-attacks on energy infrastructure are identified as risks of equal importance.

Scenarios serve as the basis for strategic measures to enhance energy security, which may conflict with pure cost optimisation. As outlined in the expert discussion, **specific events** serve as the basis: Russia's attack on Ukraine, conflicts in the Middle East (Japan's dependence on the Strait of Hormuz) and Fukushima were **stress tests** from which measures were derived. Scenarios are thus embedded in planning processes, **but continue to evolve** because real-world events repeatedly put the underlying assumptions to the test.

Risks are not regarded as an afterthought, but are **an integral part of the system assessment**, as well as the design and ongoing adaptation of precautionary measures. During the expert discussion, the focus was placed on **'what-if' scenarios** and the need for a comprehensive framework equipped to deal with such cases.

Pragmatic diversification of the energy system (including the GX strategy)

The primary objective of the current SEP is to **overcome dependence on fossil fuels whilst ensuring security of supply**. A key assumption here is that **diversity of energy sources** reduces risk and increases resilience.

Japan has formulated a national **strategy for the expansion of renewable energy** (the GX Strategy) and enshrined it in law through, amongst other measures, the GX Promotion Act and the GX Decarbonisation Power Source Act. Key components include a large-scale investment programme of around one trillion US dollars over ten years, with strong government support to mobilise private funds, the expansion of energy efficiency and renewable energy (as the 'main power source'), but also the continued use of nuclear energy, as well as the pragmatic development of hydrogen and ammonia value chains (the promotion of local hydrogen supply and the aim of reducing fuel cell costs are identified in the SEP as resilience tools) and CCS/CCUS. **Battery storage** is viewed in the SEP as a decentralised resilience tool, and aggregators are to bundle DER (PV, batteries, consumer appliances) in future and contribute to grid stabilisation. The expansion of combined heat and power (CHP) in the heating sector is also being pursued with the aim of ensuring security of supply.

Japan's medium-term objective, from the perspective of energy security, is **a broader energy mix** and a **diversified supply structure** in which the weaknesses of one source are offset by the strengths of others. However, Japan will continue to use fossil fuels for this purpose in the near future.

One example of this is hard coal: in 2022, around 30 per cent of electricity generation came from coal-fired power stations, meaning that Japan has the highest share of coal among G7 countries and, as yet, no official phase-out date. Although the government aims to reduce the share of coal to around 19% by 2030, it is relying heavily on technical transitional solutions such as the co-firing of ammonia in coal-fired power stations (e.g. a 20% ammonia blend by 2030) rather than a clear phase-out of coal.[79] The motivation behind this is to enhance resilience through coal's long shelf life. Japan no longer mines coal itself, but views **hard coal imports as part of diversifying its energy imports and boosting resilience**. Critics see this as undermining the GX strategy.[80]

4.3.3 Strategic Reserves & Stockpiling

Due to its high dependence on imports, Japan relies on a **broad stockpiling system**. This applies to oil and gas (particularly LPG), which are regarded as portable and storable energy sources that enhance resilience. Within the scope of this study, the differentiated **reserve system for oil** is particularly revealing, as the IEA, amongst others, explicitly highlights this as best practice.

Diversified Stockpiling and Reserve System

Japan has one of **the strongest strategic stockpiling systems** among IEA member countries. Of particular note is the **three-tier structure of the oil system** (**state-run**, **private and a joint stockpiling model with exporting countries**). Germany also has strategic oil reserves, but lacks a holistic approach to fuel stockpiling across all energy sources and, furthermore, has no private stockpiling model.

The Japanese oil stockpiling system combines government reserves with stockpiling obligations and public-private partnerships. In accordance with the 'Oil Stockpiling Act', JOGMEC manages government reserves equivalent to 90 days' worth of net imports. METI sets stockpiling targets every five years, which JOGMEC implements. **Japan's total reserve capacity stands at around 254 days**, which far exceeds the IEA's minimum requirement of 90 days' worth of imports. Refineries, importers and distributors are legally obliged to maintain stocks equivalent to between 70 and 90 days' worth of the previous year's consumption. JOGMEC supports these companies through loans that finance up to 80 per cent of the calculated stock levels.

In the event of an actual or imminent **disruption to supply**, METI may, by order, transfer government stocks or make them available as market loans. Upon receipt of the order, METI launches a public tender process; the physical release is estimated to take 10 to 15 days. In addition, JOGMEC may instruct companies to reduce consumption or distribution. Obligated companies must report their stock levels to JOGMEC twice a month. JOGMEC may carry out on-site inspections. Breaches may be punishable by fines running into millions (JPY) or imprisonment.

Of particular interest is the **joint stockpiling model** with the largest oil-exporting countries. JOGMEC provides tank capacity free of charge to Saudi Aramco and ADNOC.[81] In return, JOGMEC has first right of access to the crude oil stored there in the event of an emergency; in normal times, the exporters use the capacity commercially without JOGMEC paying for the crude oil until it is actually drawn down.

The situation with **gas differs structurally significantly** from oil stockpiling. For historical reasons, Japan's gas networks are highly fragmented and organised around individual city gas areas. The majority of LNG terminals are operated by electricity suppliers and city gas companies; some are joint ventures involving regional authorities. There is no legal obligation for the industry to report actual LNG stock levels. Total storage capacity covers around 36 days' worth of domestic natural gas demand. Although there is no legal obligation, electricity and municipal gas companies typically hold commercial stocks equivalent to around two weeks' gas demand. The Gas Business Act (1954) merely requires gas suppliers to submit annual gas supply plans to METI, which are assessed by the government.

For **LPG,** however, there is a **statutory stockpiling requirement covering 40 days'** worth of domestic LPG demand. **JOGMEC** provides direct support to importers **through loans** covering up to 90 per cent of the calculated amount.

4.3.4 Network & System Architecture

With regard to **grid and system architecture**, particular mention should be made of the role of **the Organisation for Cross-regional Coordination of Transmission Operators (OCCTO)**, which is to be expanded under the 7th SEP in order to enhance **forward-looking resilience planning** for the electricity grid. Here too, the approaches are of interest to Germany, as Japan, for historical reasons, has a **highly fragmented electricity grid** (50 Hz and 60 Hz), which makes it difficult to increase resilience.[82]

Establishment of new powers to centralise grid planning (electricity grid)

OCCTO was established in 2015 as **a coordination body for** Japan's **ten regional TSOs** following an earthquake and is a direct institutional outcome of that crisis. OCCTO acts as an operational link between METI and the various grid operators, but is a private organisation and not a government agency. Under the *Electricity Business Act*, all 'electric power companies' (i.e. companies that operate an electricity business or act as electricity market participants) are required to be members.[83] OCCTO's core function is the coordination of inter-regional electricity flows within Japan's fragmented electricity grid. In the German context, OCCTO's remit partly corresponds to that of the Federal Network Agency; however, there is no comparable overarching operational system control of the four German TSOs.

The **security of supply** in the Japanese electricity grid is based on a **multi-tiered system** comprising regional responsibility, inter-regional coordination and legally enshrined crisis preparedness. All TSOs and DSOs have automated remote control and monitoring systems that enable the rapid identification and bypassing of problematic grid sections.

A key element of the SEP is the targeted **expansion of OCCTO's institutional powers**. OCCTO is responsible for the expansion of supra-regional interconnectors and the supervision of local backbone networks, and is also granted additional powers in supply and demand management as well as in power station investments. This centralisation of grid planning under OCCTO aims to structurally strengthen coordination both during normal operation and in the event of a crisis. This will result in a structural separation of grid planning and grid operation.

At local level, decentralised measures complement supra-regional coordination. Local microgrids and photovoltaic installations in public buildings are to be expanded under the new SEP and will strengthen the regional resilience of the electricity grid. Strategic national planning for this is carried out centrally by METI, whilst implementation is the responsibility of local authorities.

Cooperation mechanisms to enhance resilience

In Japan, there are well-established and institutionally anchored – that is, permanently established – **forms of cooperation between government institutions and the energy industry**; these were also highlighted in the expert discussion, and their interconnection was emphasised once again.

METI and ANRE have established several **channels of cooperation** with the energy industry regarding the resilience of the energy system, organised, amongst other things, through OCCTO. The system is characterised by **permanent working groups** that bring together the private and public sectors and contribute to METI's strategy-setting, and thus to the Cabinet Office's 'Global Strategy' and even to foreign policy ('resource diplomacy').

For example, there is a **standing working group**, comprising representatives from the energy industry, on **measures to deal with natural disasters** and other **emergencies affecting the electricity infrastructure**, which advises the METI Committee on Energy Security. This committee comprises METI staff and two groups from the energy industry: firstly, the association of the ten largest electricity producers, and secondly, the Council for Transmission and Distribution Networks (whose members include all TSOs and DSOs), which is chaired by OCCTO.

The association of the ten largest electricity producers also works with ANRE within a further **public-private coordination council with the aim of** ensuring **security of supply in the energy sector**. This body collects information on stock levels and, in emergencies, can make targeted requests to private-sector companies, in particular to initiate and coordinate cooperation on fuel sharing. This coordination council thus has a strategic dimension, as it proactively coordinates stock levels.

The **cooperation formats** described are also incorporated, amongst other things, into an overarching joint, purely **government-led working group** on the resilience of the electricity sector set up by ANRE and METI, which in turn forms part of a joint committee on resilience involving OCCTO. This committee is developing a 'Master Plan for the Interconnected Electricity Grid', which organises the grid's resilience with a forward-looking approach and strategically plans the physical expansion of the grid.

The entire process is overseen by **METI and the Cabinet Office**. The national 'Self-Defence Forces' are also involved in planning a response in the event of a disaster and in ensuring security of supply, and the information gathered on the supply situation is translated into **national energy strategies** with a long-term perspective.

In summary, Japan relies on an **institutionally embedded**, **long-term partnership between the state and the energy sector**. It is noteworthy that Japan does not rely on ad hoc cooperation, but maintains **permanently** established working groups and coordination councils.

4.3.5 Conclusion: Possible Courses of Action for Germany

The analysis of the Japanese energy resilience model highlights several potential points of reference that may be relevant to the further development of the German energy security framework.

Firstly, an **institutionally organised partnership between the state and the energy sector** to increase resilience and reduce supply risks: Japan relies here on permanently established, institutionally anchored cooperation frameworks rather than on ad hoc coordination.

Secondly, and following on from this, **active resource diplomacy**: central to this is JOGMEC, the state organisation for energy security, which also brings together expertise in overseas investment and in strengthening energy and raw materials security through cooperation with the energy sector. In Germany, there is no single body that brings together these areas of expertise. Given Germany's experience of unilateral dependence on imports, the integration of energy and foreign policy through active resource diplomacy is a particularly interesting approach.

Thirdly, a **strategic prioritisation of resilience** within the framework of a scenario-based national energy strategy: Japan's Strategic Energy Plan integrates specific crisis scenarios into overarching strategic planning. Germany could benefit from a comparable overarching planning framework that embeds resilience as a cross-cutting issue within the energy sector.

Fourthly, the **pragmatic diversification of the energy system**: Japan prioritises security of supply through a broad energy mix strategy.

Fifthly, the development **of a diversified stockpiling and reserve system** for strategic resources: Japan's three-pillar model comprising state, private and bilateral reserves – including private stockpiling obligations and the joint stockpiling model – provides an example of a holistic stockpiling concept.

And sixthly, the creation of **new powers to centralise grid planning**: OCCTO's role as a supra-regional coordinating body with powers of intervention serves as an example of how a structurally fragmented grid landscape can be made more resilient through targeted institutional centralisation and cooperation with the energy sector. In this context, the differences between the Japanese and German electricity systems must be taken into account; potential courses of action for Germany in the area of grid planning should be assessed in collaboration with the TSOs and the relevant authorities.

4.4 United Kingdom

Despite some differences with Germany from an energy policy perspective (e.g. no EU membership, substantial fossil fuel production capacity from North Sea oil and gas, its island status, and a smaller industrial sector), the **UK** is, from a German perspective, an instructive example of a liberal democracy that has, in recent years, taken surprisingly robust **regulatory measures** to strengthen the resilience of its energy systems.

Resilience has been a political priority for the UK, at the very latest since the introduction of the UK Government Resilience Framework and the British Energy Security Strategy 2022. An **Energy Resilience Strategy** is due to be published in 2026, which will set out the long-term priorities of UK energy policy to ensure energy resilience both now and in the future. The sustainable transformation of the energy system plays a central role in this and is considered in tandem with resilience. In 2019, the UK set itself the target of achieving climate neutrality.[84]

The UK is closely interconnected with the energy systems of mainland Europe and thus benefits from a wide **variety of supply sources** as well as **a high degree of flexibility in the import and export** of energy. The UK produces its own offshore oil and gas, although domestic production is declining and being replaced by renewable energy.

In **the gas sector** in particular, the UK system has proved to be comparatively **very resilient** to potential supply shocks.[85] This is primarily due to the **diversified supply structure**: gas is sourced from both the UK Continental Shelf (UKCS) and the Norwegian Continental Shelf, as well as through supplies of liquefied natural gas (LNG). **Electricity generation** is based mainly on gas and renewable energy sources; electricity is also imported from and exported to continental Europe via interconnectors. The last coal-fired power station was decommissioned in 2024, whilst the share of nuclear energy in electricity generation has fallen to

around 15% over the last few decades; this is expected to rise in the future.[86] By international standards, the UK also has a **high overall level of self-sufficiency**: around
60 per cent of national energy consumption in 2023 came from domestic energy production.[87]

However, the '**multiple crises'** of recent years (including Covid and the consequences of the war in Ukraine) have **also affected the UK** and exposed existing **dependencies on imports**.[88]

With regard to energy policy resilience, there is another event that has underlined the importance of this issue, particularly in the area of grid planning: the North Hyde incident on 20 March 2025, a major power cut in West London which, amongst other things, severely disrupted operations at Heathrow Airport. Following a government inquiry, a catalogue of measures was drawn up which will be incorporated into the Energy Resilience Strategy 2026.

4.4.1 Institutional Framework & Cooperation Structures

The UK is characterised by the fact that '**resilience'** is conceived as a **task for society as a whole**, in the form of a 'whole-of-society resilience approach'.[89] This results in a broad institutional framework for responsibilities relating to resilience.

The Department for Energy Security and Net Zero (DESNZ*)*, as well as the **Cabinet Office** (in the German context: the Federal Chancellery), the **Office of Gas and Electricity Markets (Ofgem)** as the state regulatory authority for the electricity and gas markets, and the public enterprise **National Energy System Operator (NESO),** established in 2024, all play central roles in national energy resilience.

Resilience Coordination Unit and active 'resilience policy'

In 2022, the UK established a dedicated **'Resilience Directorate'** within the **Cabinet Office**, including the new role of 'Head of Resilience'. This serves to bring together all matters relating to civil protection, energy system resilience, 'social' resilience in relation to crises such as COVID, and scenario planning and risk assessment directly within a central position in the Cabinet Office. Similarly, for Germany, a position within the Federal Chancellery could be envisaged, acting primarily as a point of contact for the various sub-sectors and tasks relating to the issue of societal – and energy policy – resilience.

Furthermore, the UK pursues an **'active resilience policy**': the topic of resilience is brought into the public discourse via so-called 'Local Resilience Forums' (LRFs), in which risk assessments and measures to enhance resilience are discussed jointly with central government, local authorities, infrastructure operators, businesses and the public. During the expert discussion, it was confirmed that, from an energy policy perspective too, **ongoing cross-departmental and cross-sectoral discussion and further development of societal resilience** is important in order to break out of 'silos' and, for example, to be able to consider climate resilience in conjunction with supply resilience or infrastructure resilience, as all these areas are necessary for the resilience of the energy system.

4.4.2 Network and System Architecture

In 2023, the then Conservative UK government passed the Energy Act 2023, a comprehensive new piece of legislation aimed at accelerating the energy transition whilst ensuring the affordability and security of energy supply. Part of this involved a **reorganisation of grid planning**. This approach was continued by the Labour government, which has been in power since 2024, under the objectives of green transition and resilience, with a view to ensuring 'forward-looking' security of supply.[90]

In the 1980s, the national electricity and gas networks in the UK were privatised. Under the Energy Act 2023, it was decided to partially reverse this and to pursue a holistic system-based approach to planning, markets, energy security and resilience. This policy concept – initially known as the 'Future System Operator (FSO)' –

for an **independent system operator focused** on a **'whole system' (electricity, gas, hydrogen)** was finally implemented in 2024 with the establishment of the **National Energy System Operator (NESO)**. [91]

Institutional separation of grid operation and system management

Several successive governments, across party lines, came to the conclusion that an **overarching body** for grid planning was necessary to meet the growing demands for system integration, decarbonisation and, above all, security of supply within the energy system. Parts of National Grid were bought back and transferred to NESO.[92] The grid operator (National Grid) owns and operates the physical infrastructure (such as power lines, substations and cables) and is responsible for its maintenance and expansion. The system operator NESO, on the other hand, controls and coordinates the operation of the energy system in real time and is responsible for grid planning: NESO balances supply and demand, plans long-term system development and acts as a neutral, independent body with no commercial interests of its own in the grid infrastructure.

NESO's remit covers all types of networks, including electricity, gas and, in the future, hydrogen. The creation of NESO established a public organisation explicitly equipped with a system-wide perspective. In **Germany**, **there is no equivalent authority**; for example, in the electricity grid, both network planning and system control currently lie with the TSOs, which are primarily organised on a private-sector basis.

In the expert interview, the advantages of an institution such as NESO were emphasised in relation to the **forward-looking resilience of network planning**. As a **public cooperation**, NESO is intended to implement the **long-term political objectives** of energy policy – the 'trilemma of reliable, clean and affordable energy'[93] – independently of short-term economic optimisation pressures. At the same time, the interview highlighted that a certain degree of independence from politics is also necessary in order to be able to 'put one's finger on the problem'.

NESO's statutory mandate covers several **time horizons**: from day-to-day system management in the short term to **strategic planning** with a horizon spanning several decades: "[…] From next day to 40, 50 years ahead. So, the idea is that we operate the system of today, but we also plan the system of tomorrow."

According to expert assessment, this combination of integrated system responsibility, long-term planning expertise and institutional anchoring within the public sector represents an exception in an international comparison and has been identified as a **key building block** for the transition to a resilient, decarbonised energy system.

Grid planning incorporating positive and negative scenarios

For **long-term grid planning,** NESO draws up the **Future Energy Scenarios (FES)** and coordinates strategic grid planning on this basis. The scenarios cover a wide spectrum: from a heavily decarbonised future to a non-decarbonised development, as well as various **transformation pathways**, such as a heat or hydrogen transition. A so-called 'falling-behind' pathway, in which the intended transformation fails, is also considered. These scenarios then generate a series of resilience criteria, which NESO incorporates into its planning processes.

There are **two time horizons for the scenarios**: firstly, the FES describe a **10-year outlook** based on current political developments, from which NESO derives recommendations for the government on how much capacity should be procured on the electricity and gas markets. In parallel, NESO develops the Strategic Spatial Energy Plan, which sets out various **energy policy pathways up to 2050**. A political decision is then taken on which long-term pathway to follow, and this forms the basis for spatial energy planning in the individual regions. The national risks listed in the **National Risk Register**, which are identified in the UK in a transparent and collaborative manner (see below), are also incorporated here.

The FES are published, including the underlying datasets, so that they can be verified and subjected to scientific review. In addition, there are expert panels that support NESO in their development.

4.4.3 Scenarios & Planning Tools

Following on from NESO's use of scenarios, best-practice approaches can also be observed in the way the UK incorporates **risks** into a **cross-departmental resilience policy**.

National cross-departmental resilience strategy

Firstly, the Energy Resilience Strategy mentioned at the outset – announced for 2026 – should be highlighted as a **national and cross-departmental resilience strategy**. It was also highlighted in the expert interview as a future point of reference for institutions such as NESO.

The way in which they came about is particularly revealing: acute systemic shocks, such as the power cut caused by the North Hyde Incident, were taken as an opportunity to launch a multi-year, strategic and cross-party process to develop a resilience strategy. First, NESO published a policy review examining the North Hyde disaster; based on this, it published a Resilience Action Plan 2025, which highlighted regulatory weaknesses and vulnerabilities in the UK's electricity grid. This Action Plan is now being incorporated into the broader cross-sectoral strategy being developed by the DESNZ in collaboration with academia and industry.

The formulation of a national strategic resilience strategy, incorporating long-term scenarios and energy policy risks, is essential as a guide for investment and currently represents a gap in the German resilience framework. This measure should be viewed in conjunction with the clarification of institutional responsibilities and clear political accountability for resilience.

Introduction of a national risk register

The UK's **National Risk Register (NRR)** is a long-established institution that records various risk categories and is maintained by the DESNZ. In terms of practical energy policy, this means, for example, that NESO, as the system operator, or OFGEM, as the regulatory body, are legally obliged to report on **observed and potential system risks every year**.

Parts of the Risk Register are published. The current public version lists 89 risks across nine thematic areas (e.g. energy security or climate risks).[94] Risks include those relating to terrorism, cyber-attacks, geopolitical risks (e.g. including 'total loss of transatlantic telecommunications cables'), accidents (power cuts, gas supply disruptions), natural disasters and climate risks, as well as 'social' risks such as civil unrest. The NRR assesses the probability of occurrence and the impact for each risk. For each risk, a **Reasonable Worst-Case Scenario (RWCS)** is formulated. The NRR is aimed at specialists in crisis preparedness and resilience, as well as businesses, operators of critical infrastructure, and the scientific and research communities. The unpublished version includes an 'industry readiness' assessment and forms the basis for policy strategies.[95]

From the expert's perspective, the key added value of the NRR lies in **systematically learning from incidents and near misses** and utilising these **insights to build resilience in the future**. NESO, as a system operator, can, for example, request specific information in order to analyse incidents and near misses, identify patterns and draw lessons from them. On this basis, NESO can formulate evidence-based recommendations for the government and industry to strengthen the energy system's resilience in the long term and better address future risks.

Energy Security Stress Tests Modelled on the Financial Sector

In its report assessing the resilience of the energy system up to 2050, the National Preparedness Commission recommends the **introduction of system-wide stress tests** to **increase the resilience of the energy system**.[96] The idea behind this is modelled on the Bank of England's practices in the financial market for banks and aims to establish a uniform, system-wide assessment framework for risks in the energy system and to identify contagion risks.

In practical terms, this means developing a **common set of scenarios and stress tests** that can be applied consistently across all sub-sectors of the energy system, from electricity and gas supply right through to supply chains. These stress tests are intended to reflect both acute **supply shocks** and **systemic risks**, and to be based on detailed, sector-specific risk analyses. In addition, a standardised approach is proposed to enable all stakeholders to assess the economic impacts of these scenarios, both in terms of price and cost risks and in terms of physical supply disruptions. The aim is to create, under the leadership of DESNZ, a binding set of tools that increases transparency regarding vulnerabilities, enables comparability between stakeholders and forms the basis for targeted resilience measures across the entire energy system.

During the expert discussion, it was pointed out that **initial steps have already been taken**. For example, there is an **annual gas exercise** in which procedures, including staggered load shedding ('rota demand disconnection'), are practised in a realistic manner. Furthermore, current work in the area of contingency planning is still predominantly 'desk-based' – that is, theoretical – and is based on the development of stress scenarios and an assessment of how the system would react in these scenarios. It was also emphasised how important it is, in this context, to have a national institution such as NESO – which has no commercial interests of its own – to take on a coordinating role. This makes it possible to bring together different stakeholders.

A **practical example from Australia** is particularly interesting in relation to stress testing: there, **all market participants in the energy system** are involved **annually in comprehensive exercises**, which are conducted not only theoretically but as **real operational drills**. According to the expert discussion, this approach is considered highly instructive for the UK, even if it remains to be seen whether such a level of exercise intensity is sensible and feasible on a permanent basis and at the same frequency.

Overall, the process is still under development, with the aim of gradually defining how an effective stress testing and contingency system should be structured in practice. For Germany, however, the idea of energy security stress tests should be pursued as a means of expanding existing contingency structures for grid and energy security.

4.4.4 Strategic Reserves & Stockpiling

The United Kingdom has **only limited energy stockpiling measures** in place, particularly when viewed through the lens of the best-practice comparison in this study.

With regard to **oil,** the United Kingdom follows the IEA's '90-day rule' and accordingly maintains national stocks equivalent to 90 days' worth of net imports.[97] There is no central government stockpiling agency in the UK. Instead, stockpiling obligations are delegated to private market operators, who must provide evidence of holding the requisite stocks.

In the **gas sector**, unlike in many EU Member States and Germany, there is no significant strategic gas stockpiling at national level. There is no direct state-run storage; only limited storage activities are carried out by private market operators within the framework of market-based incentive structures.

Overall, there are **few mandatory elements** in the UK with regard to energy stockpiling: whilst there is a binding **stockpiling obligation** in the oil sector, gas and electricity supplies are primarily secured through **flexible import and infrastructure capacities**, rather than through strategic reserves.

4.4.5 Conclusion: Possible Courses of Action for Germany

The analysis of the UK's resilience measures in the energy sector highlights potential points of reference and discussion that could serve as impetus for the further development of the German energy resilience framework. Firstly, a **resilience coordination body** and an associated **active resilience policy**: with the Resilience Directorate in the Cabinet Office, the UK has established a central institutional point of contact for all resilience issues. For Germany, the establishment of a comparable coordination body within the Federal Chancellery could be considered.

Secondly, the establishment of NESO for **centralised network planning** incorporating scenarios, and the **institutional separation of network operations and system management**: NESO is a public, commercially independent institution that plans electricity, gas and, in future, hydrogen across sectors; its remit ranges from short-term system management to a time horizon of 40 to 50 years.

Thirdly, this enables the **long-term, scenario-based coordination of grid planning** and the energy system, as implemented by NESO through its **Future Energy Scenarios**. Germany lacks a comparable institutional equivalent.

However, the example of NESO's establishment and the structuring of its remit cannot be directly applied to Germany; any courses of action derived from this should only be finally assessed in consultation with the TSOs and the relevant authorities. Fourthly, a **national cross-departmental resilience strategy**: the Energy Resilience Strategy announced for 2026 is emerging from a cross-party process that involves the scientific and business communities and forms a binding framework of reference for all participating institutions.

Fifthly, the **introduction of a public national risk register**: the UK's National Risk Register systematically records risks, derives worst-case scenarios and requires institutions such as NESO to report on risks annually. This enables evidence-based learning from incidents and near-misses.

Sixthly, the idea of an **energy security stress test** modelled on the financial sector: following the example of the Bank of England's bank stress tests, a system-wide assessment framework for energy risks is being developed in the UK, which involves all stakeholders and encompasses both theoretical scenarios and operational exercises.

The latter two examples should be seen as catalysts for the German debate on resilience. However, in any considerations regarding implementation in Germany, it must be borne in mind that this should not result in additional reporting obligations that offer no added value.

4.5 Poland

Poland serves as an excellent example of security-driven **diversification of energy supply**, particularly with regard to Russia. The Polish government announced as early as 2018 that it would not renew the Yamal supply contract with Gazprom, and by the time Russia halted gas supplies in April 2022, the alternative infrastructure was largely in place. Poland not only illustrates the lead times involved in politically driven diversification, but also provides **insights into the allocation of responsibilities** for managing resilience measures. The fundamental reform of strategic **gas stockpiling** in Poland can serve as a concrete reference model for the German debate.

Coal plays a special role in Poland. For decades, domestic coal has been the guarantor of the Polish energy system's resilience to external shocks and, as a domestic resource, ensures a certain degree of supply autonomy. Although coal still fulfils this function to some extent at present, its role is increasingly weakening (due, amongst other things, to ageing power stations, dwindling economic viability and decarbonisation commitments). The key challenge in Poland is therefore to replace this traditional coal-based resilience with a **diversified portfolio** comprising renewables, nuclear power, natural gas as a bridging fuel, and storage facilities. Poland's energy security is thus undergoing a fundamental transformation – moving away from dependence on individual suppliers towards a diversified infrastructure.

Despite its reliance on domestic coal, Poland's energy system has made **progress in the energy transition**. For example, Poland has one of the fastest-growing markets for photovoltaics in the EU and is also aiming to play a leading role in the field of offshore wind energy.[98] In addition, **gas** is considered to play a central role in energy security, particularly in view of the declining role of coal in power generation.[99] The Polish model of decarbonisation also includes the planned introduction of **nuclear energy**, scheduled for the 2030s. Whilst Poland is a net exporter of coal, it is heavily reliant on imports of gas and oil. Across all energy sources and in terms of total energy supply, Poland's import dependency stands at around 45 per cent in 2024.[100] Efforts to diversify and build up reserves therefore focus in particular on oil and gas supplies.

The key measures and structures of the Polish approach to integrating resilience into energy infrastructure planning are outlined below. The key strengths of the Polish approach lie in the institutional architecture designed to strengthen the resilience of energy infrastructure, as well as the clear commitment to diversifying the energy supply.

4.5.1 Institutional Framework & Cooperation Structures

The Polish energy sector is dominated by large state-owned enterprises. The key feature of the Polish system lies in the close interdependence between the state and energy companies: ownership and operations are highly concentrated in a small number of companies controlled by the state.

Institutional framework for energy resilience

Poland's operational energy security depends on a small number of **state-controlled companies**.[101] In practice, these companies also play a significant political role in shaping national energy policy assumptions, as their investment plans, system assessments and risk analyses are directly incorporated into the state's strategic planning documents. The key player for resilience in the electricity sector is the state-owned company **PSE, which acts as the sole transmission system operator**.[102] In addition to its operational activities, PSE serves as the primary data repository for the electricity grid, which confers on the company exceptional institutional authority in both planning and crisis management.[103] Furthermore, the state-owned company PEJ, as the developer of nuclear power stations in Poland, also plays a central role in the context of energy security.[104]

In the gas sector, **Gaz-System, the sole gas TSO,** is the key player in ensuring resilience; it is also state-owned.[105] The company is responsible for the transport of natural gas, operates Poland's most important gas pipelines as well as the Baltic Pipe subsea gas pipeline, and also owns and operates the LNG terminal in Świnoujście; furthermore, it is the owner of Gas Storage Poland, a company that operates natural gas storage facilities. Oil and fuel security centres on **Orlen** (state-controlled but not wholly state-owned) as a vertically integrated oil company, which controls crude oil refining, fuel production, wholesale and a large share of retail distribution, as well as **PERN** (wholly state-owned) as the backbone for the transport, storage and logistics of oil.[106]

On the regulatory side of the energy sector, the division of responsibilities has changed in recent years.[107] The Ministry of Climate and Environment (Ministerstwo Klimatu i Środowiska) has since taken the lead on energy policy, following the dissolution of the separate Ministry of Energy in 2019. Following the government reshuffle in 2025, the **Ministry of Energy** (Ministerstwo Energii) was re-established and has since been responsible for energy policy.[108] However, the division of responsibilities has not yet been fully consolidated, meaning that responsibility for renewable energy, in particular, remains with the Ministry of Climate and Environment.[109] The independent Energy Regulatory Office (Urząd Regulacji Energetyki, URE) regulates the activities of energy market participants. It is responsible for monitoring the operation of infrastructure, granting licences to generators and concessions to system operators, and approving network tariffs.[110]

The **Government Centre for Operational Security** (Rządowe Centrum Bezpieczeństwa, RCB) is the central coordinating body for the physical and operational protection of critical infrastructure (including energy infrastructure).[111] Operators of listed critical infrastructure are required to draw up a critical infrastructure protection plan, which must be approved by the Director of the RCB. The RCB also maintains the **National Crisis Management Plan**, which contains a threat assessment and risk evaluation, including critical infrastructure, as well as a security matrix setting out the tasks and responsibilities of the various stakeholders.[112] At the international level, the RCB acts as the national point of contact for NATO and the EU. During the expert discussion, the institutional design of the Polish crisis management system was described as well thought out, with particular emphasis placed on the **RCB's role as the central coordinating body**.

Government Plenipotentiary for Strategic Energy Infrastructure

The **Government Plenipotentiary for Strategic Energy Infrastructure** represents a distinctive institutional structure. This role is currently held by Wojciech Wrochna, who is also Deputy Minister for Energy.[113] In this role, he oversees the state-owned companies Gaz-System, PERN, PSE and PEJ.[114] Furthermore, the Government Plenipotentiary and his office lead key projects relating to energy security and are **responsible for strategic investments** in the energy sector, such as the Polish nuclear energy programme, LNG terminals and interconnectors.

During the expert discussion, the creation of the Government Commissioner was deemed crucial in two respects. On the one hand, in his role as the person responsible for **strategic investments** at the highest level of government, the Government Commissioner ensures that there are no delays and that existing obstacles are removed as quickly as possible. On the other hand, the Government Commissioner , together with his office, is closely involved in **crisis situations** affecting the critical infrastructure under his supervision and performs a **coordinating role**. During the expert discussion, it was emphasised that the creation of the Government Plenipotentiary had greatly benefited the Polish system, both in the investment sector and in crisis situations, as all strategically important energy companies have a direct line of communication to the Government Plenipotentiary and his office.

Institutionally, the Polish system for energy infrastructure resilience is characterised by a combination of strong state ownership control over key companies, a specialised cross-functional role and a coordinating crisis management centre (RCB). The strength of this model lies in its ability to directly implement major strategic projects through ownership control – such as the diversification of gas supplies away from Russia, which Poland pursued early on and successfully.

4.5.2 Strategic Reserves & Stockpiling

Reform of gas stockpiling

With regard to reserve and stockpiling strategies, Poland provides a concrete reference model for Germany, particularly in the area of gas reserves. It can be observed that Poland is centralising responsibility for gas reserves as part of a **fundamental reform**.

The legal provisions governing gas supply are set out in the 'Act on Stocks'. The core obligation to date has been that sellers and end users who import natural gas must maintain mandatory stocks covering 30 days' worth of imports, which can be delivered to the Polish gas system within 40 days.[115] The costs incurred by importers as a result of the stockpiling obligation were regarded as justified operating costs and could be included in tariffs. However, this model is currently being reformed and is to be replaced by the establishment of a new model to ensure security of gas supply, based on the **central role of the Government Agency for Strategic Reserves** (Rządowa Agencja Rezerw Strategicznych, RARS).[116] As part of the reform, RARS will assume sole responsibility for the creation and maintenance of strategic natural gas reserves. The procurement of these reserves is to take place via exchanges or tender procedures. At the same time, importers will be exempted from the previous obligation to maintain their own reserves. Funding is to be provided through a **gas levy**, which, in the form of monthly payments from gas companies to a newly established fund for intervention and strategic gas reserves, will finance RARS's activities without placing a burden on the state budget.[117]

The new Polish model relieves individual market participants of the operational obligation to maintain stocks and centralises control within a single body. During the expert discussion, it was emphasised that some of the powers conferred on RARS by the reform had subsequently been revoked, meaning that RARS's remit is now narrower than originally planned. The government's decision that the management of the underground gas storage facilities at Gaz-System is better placed than transferring these powers to RARS was cited as an example. It was therefore emphasised that the **reform of gas stockpiling** has **not yet** been **fully implemented**.

Oil

As a member of the EU and the IEA, Poland is subject to legally defined mandatory oil stocks. The basis for this is EU Directive 2009/119/EC, which obliges Member States to maintain minimum oil stocks. The Polish Stocks Act stipulates a **90-day stockpiling obligation** in line with IEA requirements, which is implemented in Poland through a **mixed system** – mandatory industrial stocks held by manufacturers and traders amounting to 53 days' supply and public stocks held by RARS amounting to 37 days' supply.[118] In 2021, RARS took over the responsibilities of the Material Reserve Agency (ARM) and, in addition to establishing, maintaining and managing public reserve stocks, is also responsible for inspecting market participants subject to stockpiling obligations.[119]

Coal

The specific role of coal (its diminishing role as a key guarantor of resilience) is also reflected in reserve strategies. Coal-based energy security is ensured in particular through the **capacity market** (with special EU authorisation until the end of 2028). In 2018, the European Commission approved the Polish capacity market, designed to prevent electricity shortages, as permissible state aid for a period of 10 years.[120] In the early years, the vast majority of capacity contracts were awarded to existing coal-fired power stations.[121] Under EU Regulation 2019/943, plants with emissions exceeding 550g CO_2/kWh were only permitted to participate in capacity mechanisms until 30 June 2025; however, in August 2025, the European Commission granted Poland a derogation allowing coal-fired power stations to participate in the capacity market until the end of 2028.[122] In addition to the capacity market within the electricity sector, Poland also maintains **physical coal stocks** via the RARS. A distinctive feature, however, is that information regarding the composition, quantity and storage locations of the strategic reserves is subject to **confidentiality**.[123] Unlike the legally defined mandatory reserves for oil and gas, there is no comparable minimum stockpiling obligation for coal. Instead, coal stockpiling is carried out at the discretion of the Prime Minister, the details of which are subject to confidentiality.

4.5.3 Network and System Architecture

Diversification through a small group of state-controlled companies

Poland's diversification strategy demonstrates how **consistent political prioritisation** can drive the development of alternative energy infrastructure relatively quickly. This has enabled Poland to largely free itself from direct dependence on Russian oil and gas.[124] At the same time, the example of Poland also highlights the lead times required for consistent diversification. During the expert discussion, it was emphasised that the reorientation of the energy security strategy began long before Russia's invasion of Ukraine in 2022, with the diversification of energy supplies at its core. The start of the diversification strategy is dated to the finalisation of plans to facilitate access to the global LNG market. In 2006, the Polish government decided to build the **LNG terminal** in Świnoujście.[125] The LNG terminal was officially opened in October 2015, and the first LNG shipment arrived in December 2015. Other key elements of the diversification strategy included the expansion of the capacity of the LNG terminal in Świnoujście, the completion of the **Baltic Pipe** (to establish a direct gas transport route from Norwegian fields to markets in Denmark and Poland), and the construction of **gas interconnectors** with the Czech Republic, Lithuania, Slovakia and Ukraine.[126] The planned **Floating Storage and Regasification Unit** (FSRU) in Gdańsk Bay is regarded as a further instrument of diversification.[127] Furthermore, the planned move into **nuclear energy** is explicitly regarded as a component of diversification. A central feature of Poland's diversification strategy is the significant role played by state-controlled companies in steering the diversification of the energy supply.

Regulatory cap on the share of gas imports from a single source

In addition to the operational implementation of key diversification projects by state-controlled companies, the **diversification strategy** is also supported by regulatory measures. In 2017, the Polish government adopted a regulation mandating the gradual diversification of natural gas imports. According to this regulation, the share of natural gas from a **single source** should not exceed 70 per cent between 2017 and 2022, and between 26 per cent and 33 per cent in 2023.[128] This measure was, in effect, aimed at reducing dependence on Russian gas supplies, which in the early 2010s still accounted for around 90 per cent of Poland's gas imports. The actual diversification took place more quickly than the regulatory requirements stipulated, as by 2019 the Russian share of Poland's gas imports had already fallen to around 60 per cent.

4.5.4 Scenarios & Planning Tools

National planning documents

The formally binding national planning document in the energy sector is the 'Energy Policy of Poland until 2040' **(PEP2040)**, which was adopted in February 2021.[129] In the PEP2040, the aspect of energy resilience plays a central role, particularly with regard to the objective of diversification. Eight specific objectives are defined. These objectives include the diversification of natural gas and oil supplies, as well as the introduction of nuclear energy. The **focus on diversification** is also evident from the fact that, due to the geopolitical situation arising from Russia's attack on Ukraine, the Council of Ministers adopted the principles for updating PEP2040 in March 2022, which aim to strengthen the country's energy security and independence in light of the new situation. The rationale for the update was that the geopolitical situation necessitates a shift in strategy towards greater diversification and independence in ensuring energy security.

Another key document is the National Energy and Climate Plan **(NECP)**, which is drawn up as part of the EU's commitments. Both planning documents utilise different scenarios. In accordance with EU guidelines, the NECP employs a WEM scenario (based on the existing policy framework) and a WAM scenario (incorporating additional measures).[130] PEP2040 refers to **scenario analyses** for the energy sector, which have been incorporated as an integral part of its development.[131] These scenarios focus on assumptions regarding primary and final energy consumption (by fuel type and sector), electricity generation capacities, cross-border electricity and gas interconnections, and CO_2 price trends. However, there is no evidence that explicit crisis scenarios (e.g. in the form of geopolitical disruption scenarios) are structurally incorporated into national planning documents. During the expert discussion, it was also noted that the preparation of strategic planning documents is not perceived as a strength of Polish energy policy. As an example, it was pointed out that the documents are often out of date and have been overtaken by actual developments. For instance, the target of 2 GW of electricity generation from solar energy set out in government documents for 2030 has already been exceeded.

Grid development planning in the electricity and gas sectors is also guided by national planning documents. For instance, the sole transmission system operator, PSE, states in its grid development plan that the assumptions for the development of the transmission grid are based on existing strategic documents such as the PEP2040 and NECP.[132] The gas TSO, Gaz-System, also states that its network development planning is based on the guidelines of PEP2040 and NECP, as well as on the European network development plan, TYNDP.[133]

Crisis scenario planning primarily follows the **process prescribed by EU law** in the form of risk prevention plans for the electricity sector, as well as prevention action plans and emergency plans for the gas sector. During the expert discussion, it was also emphasised that **real-life crisis experiences**, in particular, act **as drivers** for dealing with crisis scenarios. In the electricity sector, for example, the blackout on the Iberian Peninsula was a defining event from which the Polish government and the transmission system operator PSE have drawn a number of lessons (e.g. regarding links between energy and telecommunications systems). The experiences of Ukraine were cited as another real-life crisis example, and in particular the key lesson that the foundation for a resilient energy system lies in decentralised electricity generation, including storage as a backup solution.

Geopolitical disruption scenarios for gas supply security

With regard to the EU's obligation to draw up prevention and contingency plans to ensure the security of gas supply, it is striking that, unlike Germany, Poland defines **disruption scenarios based on geopolitical factors**.[134] As part of the joint risk assessment for the Belarus risk group and the Ukraine risk group, Poland's 2019 **Preventive Action Plan** examined specific disruption scenarios focusing in particular on the interruption of gas flows from Belarus and Russia.[135] Based on this risk assessment, the need to diversify supply sources and routes was confirmed. The construction of the Baltic Pipe, the expansion of the LNG terminal in Świnoujście and the planning of a floating regasification terminal (FSRU) in Gdańsk Bay are cited as key elements.

By comparison, Germany's Preventive Action Plan does not contain any geopolitically driven disruption scenarios, but refers only to three standard scenarios in accordance with the requirements of EU Regulation 2017/1938, which relate to extreme temperatures, exceptionally high gas demand and the failure of the largest infrastructure component.[136]

4.5.5 Conclusion: Possible Courses of Action for Germany

The analysis of Poland's resilience measures in the energy sector highlights potential points of reference and discussion that could serve as impetus for the further development of the German energy resilience framework.

With regard to the institutional architecture, the distinctive institutional structure of the **Government Plenipotentiary for Strategic Energy Infrastructure** is the primary point of reference for the German debate. A similar role within the German structure could offer added value, both in terms of responsibility for strategic investments in the energy sector and in its coordinating function during crisis situations. The aspect of strong state ownership control over key companies in the energy sector is a distinctive feature of Poland that cannot be readily transferred to the German context.

The Polish reference model also provides insights relevant to Germany with regard to a consistent **diversification strategy**, such as the lead times required for diversification. Furthermore, political support in the form of a statutory cap on the proportion of gas imports from a single source could also be relevant for Germany, particularly with a view to reducing its dependence on LNG imports from the USA. A prerequisite for putting these proposals into practice would be an in-depth discussion, including with companies that may be affected.

The reform of gas stockpiling towards a model of centralised responsibility for the creation and maintenance of strategic gas reserves can also serve as a concrete reference model for the German debate on strategic gas stockpiling. Furthermore, adopting the Polish approach of examining geopolitical disruption scenarios and their implications within the framework of the Gas Preventive Action Plans is also conceivable in the German context.

4.6 Lithuania

Lithuania is particularly well-suited as a point of reference for insights into the resilience of energy infrastructure, as the country has historically been **heavily dependent on Russian energy imports**. This dependence led to increased vulnerability to political and economic influence from Russia, which made it necessary to develop robust strategies for diversifying and securing energy supplies. Lithuania's experience in establishing **alternative supply routes**, implementing a **pioneering strategy** and strengthening **European cooperation** offers valuable insights.

Against the backdrop of the country's historical experiences, **energy independence** is the guiding principle of Lithuanian energy policy. Since regaining national independence in 1990, Lithuania has pursued a strategy of energy security and the gradual reduction of its dependence on energy imports from Russia. In recent years in particular, it has pursued a **course of consistent decoupling from Russian energy imports**. Following Russia's attack on Ukraine and the ensuing energy crisis in 2022, Lithuania was one of the first European countries to completely halt energy imports from Russia. With the recently completed **synchronisation of its electricity grid with the continental European interconnected grid,** the Baltic states have successfully disconnected from the Russian-controlled system. Despite successes such as this, Lithuania's final energy consumption remains heavily dependent on imports of fossil fuels.[137] Across all energy sources and in terms of total energy supply, Lithuania's import dependency stood at around 66% in 2024.[138]

The following section outlines the key mechanisms and structures of the Lithuanian approach to integrating resilience into energy infrastructure planning. The key strengths of the Lithuanian approach lie in its clear political focus on the goal of energy independence and its consistent pursuit of decoupling from Russian energy imports.

4.6.1 Institutional Framework & Cooperation Structures

Institutional Architecture

The institutional anchoring of energy infrastructure resilience in Lithuania is characterised by a close interlinking of geopolitical security considerations with **state ownership of key enterprises**.

The **Ministry of Energy** (Energetikos Ministerija) is at the heart of Lithuanian energy policy. It is responsible for the National Energy Independence Strategy (NEIS) and the National Energy and Climate Plan (NECP). Furthermore, the Ministry of Energy is formally responsible for security of supply in the electricity sector[139] and, at the same time, acts as the owner of the key state-owned energy companies. The Ministry holds the ownership rights to the **EPSO-G** Group, whose subsidiaries include, amongst others, the electricity transmission system operator **(Litgrid)** and the gas transmission system operator **(Amber Grid)**.[140]

Litgrid is responsible for the stable and reliable operation of the national electricity system, including grid maintenance and the development of European interconnectors.[141] The company operates the strategic cross-border electricity interconnectors **NordBalt** (Lithuania–Sweden) and **LitPol Link** (Lithuania–Poland). In January 2025, the Lithuanian Armed Forces signed a cooperation agreement with Litgrid, focusing on improving the security of the NordBalt electricity interconnector with Sweden and other critical energy and telecommunications infrastructure in the Baltic Sea.

Amber Grid operates, maintains and develops the gas transmission network. In this capacity, Amber Grid also performs key functions relating to the **LNG terminal in Klaipėda,** which is essential for Lithuania's gas supply. In addition to connecting the terminal via an Amber Grid gas distribution station and transporting the regasified LNG onwards from Klaipėda, Amber Grid is also responsible for managing the funds, which are earmarked for the LNG terminal, its infrastructure, operating costs and the reasonable costs of supplying the required volume of LNG.[142]

Through the **Ignitis Group** and its subsidiaries, the **Ministry of Finance** (Finansų Ministerija) oversees, in particular, investments in electricity and heat generation; and, through its ownership of the distribution system operator ESO, it also oversees electricity and gas transmission at distribution network level.[143]

The **National Crisis Management Centre** (NKVC), the establishment of which was decided at the end of 2022, acts as the central operational body for managing crises and emergencies.[144] The Centre is organisationally attached to the Government Chancellery and is regarded as the most important institution for crisis prevention and management. It acts as a **central coordination point** between ministries and authorities. In doing so, it assumes an overarching coordination role across the relevant ministries and authorities for all types of national crises, which may also include energy-related crises (such as widespread power cuts, threats to critical infrastructure or supply disruptions).

The National Energy Regulatory Council (NERC) is responsible, in particular, for regulating access to Lithuania's energy infrastructure and for price regulation within the energy sector.[145] At an operational level, the NERC also monitors compliance with safety and reliability standards, such as the SAIDI and SAIFI indicators for the reliability of the electricity supply.[146]

State ownership as a control mechanism

With regard to cooperation between the state and companies, the central approach in Lithuania is to use state ownership of key companies as a **governance tool**.

The most important operational governance tool is the so-called **'Letter of Expectations**'. In accordance with the state ownership guidelines, the majority shareholder (the Ministry of Energy for the EPSO-G Group and the Ministry of Finance for the Ignitis Group) sends such a Letter of Expectations to the respective parent company at least every four years, setting out the state's objectives and priorities.[147]

In the Ministry of Energy's Letter of Expectations for the EPSO-G Group, **energy independence and energy security** are among the primary expectations.[148] For example, it states that the EPSO-G Group must ensure the independence and autonomy of the Lithuanian electricity grid, as well as its integration into the continental European electricity grid. Furthermore, the group is expected to implement restrictive measures regarding the supply of energy and energy resources from countries that, according to the National Security Strategy, pose a threat to Lithuania's national security. The central role of the Letter of Expectations is evident, amongst other things, from the fact that Amber Grid's Network Development Plan explicitly refers to the Letter of Expectations and the expectations set out therein.[149]

The Ministry of Finance’s Letter of Expectations for the Ignitis Group also places a clear focus on energy security and resilience.[150] This is evident from the fact that contributions to energy security and to increasing resilience are among the strategic priorities.[151] This includes, amongst other things, the expectation that the electricity distribution network will be made resilient to external factors.

The **National Energy Independence Strategy** serves as an overarching strategic framework, to which the Letters of Expectations of both groups explicitly refer. The corporate groups must contribute to the objectives set out therein and integrate them into their long-term and short-term business priorities. The focus here is on achieving and implementing the objectives of the National Energy Independence Strategy, which are directly linked to the activities of the corporate groups, as well as on ensuring the resilience of the strategic infrastructure managed by these corporate groups.

During the expert discussion, it was emphasised that, on the one hand, the key companies are working very resolutely to ensure energy security and resilience, driven by state ownership and the explicitly stated expectations. It was also emphasised that, particularly in light of historical experience and reinforced by Russia’s war of aggression against Ukraine, energy security is taken very seriously; consequently, key enterprises have proactively played a central role in strengthening energy resilience, particularly in recent years.

4.6.2 Scenarios & Planning Tools

The National Energy Independence Strategy (NEIS) serves as **the key strategic planning tool** for Lithuanian energy policy. Since its initial publication in 2012, the strategy has been updated twice. The current version, which was adopted by Parliament in 2024, sets out an ambitious vision for Lithuania’s future energy system.[152] Key objectives for 2050 include both a climate-neutral energy system and **energy independence**. Energy independence is defined here as aiming for national self-sufficiency in energy resources and the elimination of net imports (with the exception of uranium imports). The ultimate goal is therefore a climate-neutral energy supply based on local energy generation by 2050. Compared with the German context, it is particularly interesting to note that Lithuania’s energy policy explicitly places climate neutrality and energy independence on an equal footing in terms of importance.

Energy independence as a key determinant of scenario development

The NEIS is based on a **scenario analysis** of the energy system’s development. To this end, the study ‘Lithuania Energy System Transformation to 2050’ was carried out.[153] This analysed possible changes to the Lithuanian energy system up to 2050 using three main scenarios, each of which takes into account regional energy trends, the development of energy infrastructure in Lithuania, the market situation and the legal framework. Based on this analysis, the Lithuanian government developed a roadmap scenario designed to ensure an optimal balance between energy independence, the reduction of greenhouse gas emissions, exports of hydrogen and derivatives, and the overall costs of the energy system. Both the network development plan of the electricity transmission system operator Litgrid[154] and the network development plan of the gas TSO Amber Grid[155] refer to the NEIS and the scenarios set out in the study ‘Lithuania Energy System Transformation to 2050’.

The network development plan of the gas TSO Amber Grid notes that geopolitical threats are assessed in collaboration with government authorities.[156] However, it is not clear whether and to what extent these threats (e.g. in the form of geopolitical disruption scenarios) are structurally incorporated into network planning. **Crisis scenario planning** primarily follows the process prescribed by EU law in the form of risk prevention plans for the electricity sector, as well as prevention action plans and emergency plans for the gas sector.

Energy independence as a benchmark for the cost-benefit analysis of resilience measures

The strategic importance of the goal of energy independence, enshrined in the NEIS, is illustrated not least by the fact that the EPSO-G Group's strategy also refers to the NEIS and the goal of energy independence as a guiding principle.[157] In the context of its operational implementation, it is possible to observe the impact that establishing energy independence as a strategic objective has on the **cost-benefit assessments of resilience measures**. Rather than purely cost optimisation with a view to achieving climate neutrality, the enshrinement of energy independence in the NEIS ensures that strategic resilience gains in importance and plays a key role. The **synchronisation of the electricity system with the continental European grid** provides evidence of this. From a purely cost-efficiency perspective, this project was difficult to justify – following the disconnection from the post-Soviet BRELL interconnection system, electricity prices in the Baltic states initially rose significantly, triggering concerns regarding energy costs.[158] Nevertheless, the project was prioritised because strategic resilience – in the form of decoupling from the Russian-controlled system – was regarded as the overarching objective. With regard to the cost-benefit considerations of resilience measures, the expert discussion also highlighted the Lithuanian mindset, which leads to a high level of intrinsic motivation to strengthen energy resilience. A mix of funding mechanisms is used to finance resilience measures: funding via tariffs (approved by the National Energy Regulatory Council as part of investment plans), funding from the national budget, and funding from EU funds (increasingly in cooperation with the Baltic states).

With regard to **quantifying resilience**, it is notable that the NEIS places a strong emphasis on reducing import dependency. Thus, within the framework of the NEIS, impact indicators – including interim targets – are formulated to achieve the overarching objectives of the NEIS. The primary indicator here is the **Energy Dependency Index**, which indicates the share of net imports in total energy consumption.

Energy independence as a stable political consensus

During the expert discussion, the significance of the NEIS was emphasised, particularly in light of the fact that – thanks in part to broad stakeholder participation (with the active involvement of state-owned and private companies) – the strategy has been successfully established as a **long-term vision**. It was also highlighted that, over the years and through the two updates to the NEIS, the resilience component has been given increasing weight, with more ambitious targets defined in this regard. A particular strength of the NEIS highlighted is that the central goal of **energy independence**, in particular, serves as **'common ground'** and that this goal is upheld across legislative terms, regardless of the government's party political composition.

In this context, it is important to take into account Lithuania's historical context and broader circumstances, which have led to the objectives of consistently decoupling from Russia and reducing overall dependence on energy imports being deeply rooted in society. Against this backdrop, Lithuania's experiences cannot be directly applied to Germany. Nevertheless, the significance of the NEIS as a strategic planning tool in the context of energy resilience – particularly with regard to setting clear targets and maintaining them across parliamentary terms – provides an important insight.

4.6.3 Network and System Architecture

Consistent decoupling from Russian energy imports

In addition to political clarity regarding the goal of energy independence, the **course of consistent diversification** and decoupling from Russian energy imports represents a further key strength of the Lithuanian approach to strengthening energy resilience.

A key component of this is the **early commissioning of an LNG terminal**. With the liquefied natural gas tanker 'Independence', which has been operating as an LNG import terminal in the port of Klaipėda since 2014, Lithuania has brought one of the first LNG terminals in Europe into operation.[159] The LNG terminal was designed and built to fully meet the needs of the Lithuanian gas market (even on the coldest winter days) . Thanks to the LNG terminal, Lithuania was also one of the first EU Member States to stop relying on Russian gas following Russia's invasion of Ukraine. The example of the LNG terminal in Lithuania demonstrates the value of early infrastructure diversification as opposed to a crisis response.

Another key aspect is the systematic decoupling from geopolitically risky energy suppliers (in Lithuania's case, Russia and Belarus in particular). This approach is also being driven forward politically. For instance, Lithuania has regulations in place that restrict energy imports from countries deemed a **threat to national security**. In 2017, the Lithuanian Parliament passed a law classifying the Belarusian Ostrovets nuclear power station as unsafe and, amongst other things, as a threat to national security.[160] This law includes an obligation to boycott electricity imports from this plant. In addition, a general ban on electricity imports from third countries with nuclear power stations classified as unsafe was introduced in 2018.[161] When the Belarusian Ostrovets nuclear power station went into operation in November 2020, the Lithuanian grid operator Litgrid cut off the flow of electricity from Belarus, thereby implementing the legal requirement.[162] A similar regulation also applies to natural gas imports. In June 2022, parliament passed amendments to the Natural Gas Act, restricting access to the Lithuanian gas transmission system and the Klaipėda LNG terminal to suppliers from countries that do not pose a threat to national security.[163] An exception to this applies to Russian gas transiting through Lithuania to the Russian exclave of Kaliningrad.[164]

European grid synchronisation

The decoupling from Russian energy imports is being supported by **strong European coordination**. The synchronisation of the Baltic electricity grid with the continental European grid in February 2025 is a key resilience project that Lithuania has been driving forward for more than a decade, and which marked the permanent disconnection from the BRELL grid – the last remaining link to Russian energy dependence.[165] In parallel, Lithuania has built several **interconnectors**, thereby strengthening European interconnection as part of its efforts to enhance energy resilience. These include the NordBalt electricity interconnector to Sweden[166] and the LitPol Link to Poland[167], as well as the GIPL gas pipeline to Poland.[168]

During the expert discussion, it was emphasised that energy dependence on Russia had been identified as a problem since independence in the 1990s. However, initially only small steps were taken, without any significant progress. In the 2000s, the path towards decoupling was strategically incorporated into the energy strategy and, as a result, pursued more consistently. The approach in Lithuania shows that, due to historical experience, decoupling from Russian energy imports had already been consistently pursued even before Russia's war of aggression against Ukraine in 2022.

4.6.4 Strategic Reserves & Stockpiling

Lithuania's reserve and stockpiling strategy stems primarily from the obligations arising from its EU membership. As coal now plays virtually no role in the Lithuanian energy mix, there are no strategic coal reserves or corresponding stockpiling regulations.[169]

Oil

As domestic crude oil production is negligible, Lithuania is entirely dependent on imports to meet its crude oil requirements.[170] The 'Law on State Stocks of Petroleum Products and Oil' transposes the EU Directive on oil stocks (2009/119/EC).[171] The Act specifies the level and type of oil stocks and regulates the powers to activate emergency measures. Under the law, the country's oil reserves must be sufficient to cover 90 days of average daily net imports or 61 days of average daily domestic consumption in the previous year, whichever is higher. This is in line with the **EU regulation on oil stockholding**. In Lithuania's case, the corresponding reserve level is 90 days of net imports. The Lithuanian Energy Agency (LEA) is responsible for maintaining 30 days' worth of consumption from publicly held emergency stocks, whilst industry is responsible for maintaining the remaining stock (required to cover 90 days' net imports). The stockpiling obligation applicable to industry is recalculated annually.

Gas

Lithuania has no natural gas reserves and no commercial gas storage facilities of its own.[172] For its strategic reserve, Lithuania uses the **Inčukalns underground gas storage facility in Latvia**, which is the only operational underground gas storage facility in the Baltic region.[173] The regulatory framework for this is provided by the EU's Gas Security of Supply Regulation (EU/2017/1938) and the Gas Storage Regulation (EU/2025/1733). With regard to the rules on storage levels, a special provision applies to Member States without their own storage facilities (such as Lithuania), whereby 15 per cent of their annual domestic gas consumption may be stored in facilities in other Member States.[174] In contrast to the oil sector, where the state itself holds reserves, gas reserves are held **decentrally by the suppliers**. Suppliers are responsible for ensuring an uninterrupted gas supply to vulnerable consumers and must maintain gas reserves for both these customers and those with contracts guaranteeing uninterrupted supply.[175] The Lithuanian model is therefore structured on a customer-by-customer basis – not as a flat-rate percentage of the total volume marketed, but linked to the specific supply obligation towards protected customers. In addition, further requirements apply regarding emergency planning obligations and annual safety reporting. All companies participating in the gas market are obliged to have their own emergency plans and must, in the event of a crisis, provide information to the TSO, which forwards it to the Ministry of Energy. Furthermore, gas suppliers must submit an annual security report to the Ministry of Energy, including information on the volume and location of their stored gas supplies.

Electricity

In the electricity sector, Lithuania is focusing on resilience through diversification (alongside domestic generation) by synchronising with the continental European grid and developing interconnectors. As part of a joint resilience programme involving Estonia, Latvia, Lithuania and Poland, Lithuania has also announced that, in addition to the physical protection of critical infrastructure, an emergency and crisis reserve for critical grid components is to be established.[176]

4.6.5 Conclusion: Possible Courses of Action for Germany

The Lithuanian reference model offers a number of potential points for discussion and reference in the German context. A key strength of Lithuania lies in establishing energy independence as a political guiding principle within the framework of its central strategic planning instrument, the National Energy Independence Strategy. Even if the goal of energy independence cannot be meaningfully transferred one-to-one to the German context, it appears to be a key best practice to draw up a strategic planning document that defines concrete targets regarding energy resilience and establishes them across parliamentary terms.

As with the Polish model, state ownership of key enterprises in Lithuania and the associated regulatory framework constitute a key aspect which, due to the different framework conditions in Germany, cannot be directly replicated. Lessons can also be drawn for Germany from the consistent shift away from Russian energy imports towards European coordination. By bringing an LNG terminal into operation at an early stage, Lithuania illustrates the lead times required for diversification. Furthermore, the political support provided by excluding energy imports from states that pose a threat to national security offers a model that is theoretically transferable. In the German context, Lithuania's strong European coordination is also an aspect that serves as a relevant example of best practice.

4.7 Further international experiences

4.7.1 Israel

Israel provides a reference case that differs significantly from the European case studies in particular. As an **'energy island'** isolated from its neighbours in terms of energy supply and facing a **permanent threat**, Israel maintains systematic **crisis preparedness as a permanent state of affairs**. Despite the differing circumstances, certain aspects can be drawn from Israel's experience that may serve as a useful reference for energy resilience in Germany.

A key aspect is the **institutional integration of civilian and military risk analysis**. The central body for national crisis preparedness is the National Emergency Management Authority (NEMA), which was established in December 2007 in response to the experiences of the Second Lebanon War and reports to the Ministry of Defence.[177] **NEMA** plays a coordinating role and consolidates the risk assessments of the relevant ministries (including the Ministry of Energy) into a single National Risk Analysis Document, which is submitted to the Cabinet and adopted there as a binding decision for all ministries.[178] Furthermore, the Cabinet determines further measures, taking into account NEMA's recommendations. A distinctive feature is the high level of civil-military integration: threat analysis is carried out jointly with the armed forces. Scenario planning is therefore directly linked to military situation analyses. The head of NEMA, for example, publicly outlined a scenario in which a military incident could cut off around half the population from the electricity supply for at least one day.[179]

The core principle of the stockpiling and reserve strategy is the **dual-fuel approach**, which stems from the country's high dependence on gas. The dual-fuel regulation addresses a key vulnerability in the Israeli energy system: the natural gas supply is delivered via just two pipelines from offshore fields to the coast, with no storage capacity within Israel.[180] Furthermore, gas-based generation is concentrated at a few sites, which are regarded as single points of failure. The dual-fuel regulation requires power stations to be capable of operating not only on natural gas as their primary fuel but also on a liquid secondary fuel (usually diesel), in order to maintain the electricity supply even if the natural gas infrastructure fails. Most power stations are equipped with this dual-fuel capability.[181] The dual-fuel regulation is an example of how the operating licence is used as a gatekeeping mechanism in Israel: compliance with high safety and resilience standards is a prerequisite for plants to be allowed to operate at all.

In addition to their dual-fuel capability, **coal-fired power stations** will not be shut down completely but will be retained as a **strategic reserve**. The Ministry of Energy's target for 2030 is to replace coal primarily with natural gas, with the aim of achieving a mix of 70 per cent natural gas and 30 per cent renewables in the electricity mix.[182] The coal-fired power stations are to be retained as generation capacity for emergencies. During the expert discussion, it was emphasised that, thanks to continuous maintenance, the coal-fired power stations should be operational again within a very short time.

Another aspect of Israel's approach to resilience is the role of rooftop solar panels, which are explicitly regarded as a **decentralised resilience measure**. During the expert discussion, it was emphasised that many aspects of the Israeli energy system are too centralised and that, as a result, there is an explicit incentive for people to generate their own electricity in close proximity to where it is consumed. Firstly, Israel has a mandatory solar roof scheme for all newly constructed residential buildings and certain non-residential buildings.[183] In addition, there is a government feed-in tariff per kWh of solar power, which is higher for decentralised rooftop PV systems in urban areas (major cities with more than 50,000 inhabitants). This scheme explicitly factors in the benefits of decentralised electricity generation in the event of outages at individual centralised generation plants. Israel is thus explicitly addressing the spatial logic of resilience through volume control (in the form of the solar roof mandate) and through **additional economic incentives for rooftop PV systems** in the immediate vicinity of consumers.

During the expert discussion, it was emphasised that, due to Israel’s specific context, there is a holistic understanding of resilience and security, characterised by the fact that maintaining critical societal functions (such as the energy supply) is accorded a very high priority across society as a whole. Given Germany’s different security situation, it is not to be expected that the concept of resilience will be given the same priority in Germany as in Israel when weighed against other considerations (such as climate neutrality targets or cost-efficiency). Nevertheless, the Israeli reference model offers a number of insights that are also relevant to the German debate on strengthening the resilience of energy infrastructure planning.

4.7.2 Ukraine

In addition to the Israeli model, it is worth taking a second look at a country facing an even more extreme security situation. Since the start of Russia’s war of aggression in February 2022, Ukraine’s energy system has become the **target of systematic attacks on energy infrastructure**. Ukraine must therefore simultaneously operate, protect and overhaul its energy system whilst under constant attack. This **exceptional situation** has given rise to practical knowledge that is increasingly being used internationally as a benchmark for resilience concepts. The Kyiv-based **DiXi Group**, an independent think tank that provides analytical support to the Ukrainian energy sector, plays a key role in the systematic analysis of these experiences. With Russia’s war of aggression against Ukraine, energy security has moved to the forefront of its work. In this context, the DiXi Group’s weekly situation reports on energy infrastructure, grid stability and systemic risks have become particularly significant. In its report **‘Holding the Grid: Ukraine’s Energy Resilience Playbook’,** published in March 2026, the DiXi Group has distilled the key lessons from four years of war into eleven principles of resilience, thereby presenting a practical framework that is relevant far beyond the Ukrainian context.[184]

The report focuses in particular on the practical implications for the **‘resilience-by-design’ strategy** in the areas of infrastructure planning, investment, operations and governance. Key elements include flexibility, grid resilience, rapid repair capabilities and integrated protective measures against physical and cyber-based attacks, in order to maintain critical services even under attack conditions, guarantee the **rapid restoration of supply** and prevent systemic breakdowns.

Since February 2022, the Ukrainian energy sector has been subjected to **sustained missile and drone attacks**. Over time, both the frequency and the tactics and complexity of the attacks have increased. Initially, fuel logistics and large generation plants were particularly affected. In the spring of 2024, for example, more than 9 GW of available generation capacity was destroyed. The attacks have increasingly spread to smaller generation plants and distribution networks, and from 2025 onwards also to gas infrastructure and district heating systems. These systematic attacks are aimed not only at causing short-term outages, but also at destabilising the supply in the long term and making rapid restoration more difficult. At the same time, the **outdated infrastructure** dating from the Soviet era represents a critical structural weakness and a key challenge, for example due to long lead times for spare parts.

The attacks have made it clear that high power station capacities alone are not sufficient if the transmission and distribution networks are not resilient and cannot be restored quickly. Against this backdrop, the understanding of energy security has evolved from a purely capacity- and demand-oriented approach towards a **broad and comprehensive concept** of operational capabilities: flexibility, grid redundancy, modular and distributed generation capacities, and rapidly available repair solutions are crucial for system stability and resilience. The synchronisation with the European ENTSO-E grid, which has been in place since March 2022, is also an important external resource for greater resilience; however, its benefits are limited by specific operational and technical import restrictions, in particular actual transmission grid bottlenecks, capacity limits and ‘N-1’ security.

The following are the **key principles of energy resilience** explicitly identified in the report, based on Ukraine's energy supply measures from 2022 to early 2026:

1. *Reduce strategic dependence on centralised generation;*
2. *Protect and expand flexible generation;*
3. *Prioritise grid resilience to ensure generation capacity use;*
4. *Consider cascading dependencies in urban energy systems as a distinct risk;*
5. *Ensure Interconnectivity as a strategic resilience factor, but account for constraints;*
6. *Standardise equipment and repair approaches to accelerate recovery;*
7. *Integrate air defence, physical (engineering) and cyber protection into energy security planning;*
8. *Build logistics resilience, reserves and clear prioritisation for supplying primary energy sources;*
9. *Strengthen crisis communications and grassroots preparedness;*
10. *Enable industrial adaptation through backup supply and energy management;*
11. *Use regulatory policy to accelerate reconstruction and restore market stability.*

The practical lessons to be learnt from this are manifold. Reducing **strategic dependence on centralised power generation** does not mean doing away with large-scale power generation, but rather supplementing it with **decentralised capacity** for critical loads, modular solutions and a planning framework for regional security of supply. **Flexible generation** should be the primary objective, as system stability depends less on total capacity and more on rapidly responding resources that cover peak loads and provide reserves. At the same time, attacks on flexible generation have a disproportionately large systemic impact, which must be taken into account.

Grid resilience determines whether generation capacities can actually be utilised. The grid infrastructure (substations, transmission lines, distribution nodes) – and not just generation – can also restrict supply in the event of attacks. For this reason, redundancy, sectionalisation and standardised, rapidly deployable recovery solutions form the operational basis of grid resilience.

Energy security requires multi-layered protection – integrated from the outset – comprising physical, air defence and cyber measures. Experience from wartime shows that facilities deteriorate faster than they can be restored if no protection is in place; therefore, protection must be integrated into programmes from the very beginning. Furthermore, the speed of recovery depends more on **standardisation** than on funding. A standardised nomenclature for critical spare parts, pre-established storage centres and standardised supply configurations reduce recovery times from weeks to days. The resilience of oil and gas supplies also requires decentralised storage, clear prioritisation rules and maintained import capacities. Supply chains based on centralised storage are particularly vulnerable.

Ukraine's experience underscores that resilience is not the hallmark of a single facility, but arises from a **bundle of capabilities**: decentralised and flexible generation, robust and repairable grids, standardised recovery logistics, multi-layered protection, cross-sector urban planning, disciplined communication, adaptability on the demand side, and regulation that eliminates friction without removing accountability. Institutionalising these capabilities enables the transition from ad hoc responses to a sustainable resilience model.

4.7.3 China

As part of the international best-practice analysis, a look at **China's Five-Year Plan** is also illuminating. China is not only the world's largest energy consumer and a dominant producer of key transformation technologies, but has also, in recent years, established itself as a **pioneer in the systematic development of energy resilience**. The Five-Year Plans bring these measures together within a consistent framework, thereby offering an insight into the energy strategy that not only shapes global markets but can also serve as a reference model for own resilience concepts.

China's 15th Five-Year Plan for Economic and Social Development, which was adopted by the National People's Congress on 12 March 2026, sets out the political and economic guidelines up to 2030. Its central focus is on **technological, economic and energy independence**. The Five-Year Plan is regarded as China's most important strategic document and will be further elaborated in the coming years through detailed sub-plans.[185] At the heart of the plan is the objective of achieving **technological autonomy** and strengthening China's structural independence from foreign countries. As part of this initiative, particular emphasis will be placed on the national development and promotion of key emerging technologies such as semiconductors, artificial intelligence, robotics, biotechnology, quantum computing and 6G mobile communications. This will be accompanied by a significant increase in overall investment in research and development.[186]

It is striking that the plan sets out the lowest growth rate in many years. China is thus preparing for **structurally lower growth** whilst seeking to strengthen its own industrial and geopolitical position. The plan's two top priorities are therefore the development of a modern industrial system and the acceleration of technological independence and leadership. The Five-Year Plan builds on existing industrial policy strategies, but the now clearly articulated **focus on self-reliance and resilience** marks a distinct **shift in priorities**. The promotion of domestic consumption is also emphasised in this context: a more robust domestic market is intended to **reduce structural dependence on exports** and enhance economic stability.[187]

In its **energy policy**, China is consistently pursuing the **principle of self-sufficiency**. The expansion of wind, solar, hydro and nuclear power is primarily aimed at reducing dependence on imports rather than at cutting emissions. Although China is aiming for an emissions reduction of around 17 % by 2030, its climate policy ambitions remain limited overall. The focus remains on retaining or dominating key value chains – such as in the solar, wind, battery, electric vehicle and, in future, hydrogen sectors – within the country. Thus, energy production capacity is set to increase further, whilst a complete phase-out of coal is not mentioned. Compared with previous reports, the overall ambition in climate policy is limited, and dependence on coal persists.[188]

In many respects, the 15th Five-Year Plan represents a continuation of the existing political and economic direction. However, the **clear focus on autonomy** is new and reflects the current geopolitical uncertainty and turmoil. Overall, the plan thus demonstrates that technological, economic and energy policy resilience and independence are China's new guiding principles.

4.8 Comparative summary

The six country chapters and three digressions examine approaches to resilience in very different contexts – ranging from smaller economies with links to Russia (Finland, Sweden, Poland, Lithuania) to major industrial nations outside the EU (the UK, Japan, China) and countries facing acute threats (Israel, Ukraine). Despite this heterogeneity, seven recurring **best-practice approaches** can be identified. The brief look at Germany is not intended to imply that individual best practices are directly transferable. The following remarks are not intended as direct templates to be copied, but rather as examples which, with regard to the German context, outline a range of possibilities within which options for action and questions of implementation become more clearly apparent.

4.8.1 Institutional consolidation with clear leadership

All the countries under comparison have a designated central body that brings together operational, regulatory and, frequently, financial responsibilities under one roof. Sweden goes the furthest with Svenska Kraftnät — a single institution combining the transmission system operator, the electricity emergency authority and the co-financing body for distribution system operators. The UK has created NESO, a system operator institution wholly owned by the public sector; Poland and Lithuania use state ownership as a control mechanism; Japan coordinates via the METI-ANRE-JOGMEC triad. By contrast, the German structure is highly decentralised (TSOs, BNetzA, BMWE, BMI, security authorities). The Swedish experience shows that investments in resilience accelerate significantly when **regulatory obligations and co-financing** are brought together under a single body.

4.8.2 A strategic resilience strategy as a political framework

In the countries under comparison, there is generally an inter-ministerial resilience strategy anchored at a high political level: Finland's *kokonaisturvallisuus*, Sweden's Total Defence Decision 2025–2030, the UK's Energy Resilience Strategy announced for 2026, Japan's 7th Strategic Energy Plan and Lithuania's National Energy Independence Strategy. These documents establish resilience as a key objective alongside decarbonisation and cost-efficiency, and provide a frame of reference for subordinate planning instruments — a function that is systematically lacking in Germany. Lithuania takes a more focused approach, declaring energy independence to be a central objective, as underlined by the costly synchronisation of its electricity grid with continental Europe.

4.8.3 Public-private partnership structures

In none of the countries under comparison has resilience policy been imposed exclusively by the state or designed for the short term; rather, it is embedded within permanently established structures at the interface between the private sector and government action. Finland's pool system under NESA is prototypical in this regard – described by a Finnish government official as the 'crown jewel' of the model. However, the Finnish case also reveals a key limitation: a voluntary approach works from an organisational perspective, but encounters difficulties as soon as significant **investment in preparedness capacity** is required. The Swedish solution – a regulatory obligation combined with co-funding under a single authority – may provide an answer to this gap evident in the Finnish model.

4.8.4 Stockpiling beyond the EU minimum standard

The countries examined that are significantly dependent on imports go substantially beyond the EU and IEA minimum standards: Finland, with around five months' worth of fuel imports in stock; Japan, with 254 days' worth of oil plus 40 days' worth of LPG, as well as the joint stockpiling model with Saudi Aramco and ADNOC; Poland, with a coal stockpile held in confidence via the RARS; and Sweden, with a clear separation between market-based effect reserves and state-administered beredskapsreserve on its own legal basis. Two elements are particularly revealing for Germany: the **reservation of specific generation facilities outside the market** on the sole grounds of resilience – a category not provided for in German law – and the **cross-fuel approach** taking into account the storability of hard coal, which would conflict with the German Coal Phase-out Act.

4.8.5 Controlled diversification

In the countries under comparison, diversification is not expected to be a market outcome but is instead state-directed. Poland's 2017 regulation set an **upper limit on the share of natural gas from a single import source** (70 per cent until 2022, 26–33 per cent from 2023 onwards) – an instrument unique within the EU, accompanied by state-funded infrastructure projects. Lithuania employs import bans. Japan, through JOGMEC, operates via equity investments in production projects and loan guarantees – a model with no German equivalent. It is important to note the **lead times** involved in many cases: Poland's transition away from Russian gas supplies was only achieved sixteen years after the 2006 policy decision on LNG.

4.8.6 Stress scenarios and risk architecture

The UK's National Risk Register is the most detailed approach — 89 publicly published risks across nine thematic areas, each with a 'Reasonable Worst-Case Scenario' and an annual reporting obligation for NESO and Ofgem. NESO supplements this with Future Energy Scenarios featuring explicitly negative pathways ('falling behind' scenario). Finland operates on the basis of the 'open list' approach, whilst Japan uses specific real-world events as stress tests. By contrast, the German Gas Prevention Plan remains limited to the three EU standard scenarios; geopolitically driven disruption scenarios are not designated as a binding basis for planning. It is also worth noting that the countries under comparison have **not achieved full integration** of risk architecture and network planning either – the integration of stress scenarios into network planning is more of a target than an implemented standard.

4.8.7 Regional resilience and island operation embedded in planning

Sweden provides the clearest example: the *electricity supply zones* divide the country into supply areas, black start capabilities are practised operationally in several regions, and the Styrel system prioritises the power supply to critical consumers on a bottom-up basis. Japan combines centralised grid planning under OCCTO with local microgrids, whilst Israel addresses resilience through mandatory rooftop solar panels and differentiated feed-in tariffs. Within the German framework, island operation is enshrined in regulation (Paragraph 13 of the Energy Industry Act), but is organised in a decentralised and market-based manner. There is no systematic zoning of supply areas, black start resources or planned island operation options. Island operation remains **a technical fallback for grid restoration — it is not a planning-based element of crisis preparedness**.

Two cross-cutting findings run through the chapters on the federal states. Firstly: the triggers for strategic resilience reforms are almost invariably specific events — the Balticconnector incident and Finland's accession to NATO in 2023, the North Hyde incident for the UK, the 2011 earthquake for Japan, the 2014 annexation of Crimea for Lithuania, and the first Russian gas dispute in 2006 for Poland. Reform windows therefore frequently open following acute crises, rather than as a result of abstract threat analyses – a finding of significance for the German situation and the current reform window. Secondly: no country under comparison has robust rules for a **'grey area'** between a purely market-based regime and a full crisis regime. This structural gap exists in Germany in a comparable form.

The seven strands paint a picture of integrated strategic resilience planning, **the building blocks** of which **are not fully present in any single country**, but are present in various forms across different countries.

5 SCENARIO-BASED APPROACHES AND INSTITUTIONAL BLUEPRINT

5.1 Classification of scenarios

Both the state and businesses require sound scenario planning in order to prepare adequately for the future. A systematic classification of scenarios helps to make an appropriate selection in this regard.

Analysis of the six countries examined shows that a systematic typology of scenarios must serve a dual purpose: on the one hand, it should organise the diversity of empirically observed crisis and stress situations; on the other, it should guide planning measures. Both require that the typology be structured not according to the **causes** of disruptions, but according to their **effects on the energy system**. This shift in perspective is methodologically sound: a disrupted import route has the same consequences, regardless of whether it is triggered by geopolitical escalation, targeted sabotage or a technical accident. The measures that make an energy system resilient to such events are largely identical. A consequence-oriented classification thus provides the framework for meaningfully categorising the measures identified in the country analyses.

The following classification was derived inductively from the country analyses and draws on the scenario patterns repeatedly observed during the course of the research. It is structured along **two dimensions**: the impact structure and the time dimension. The time dimension is relevant to planning because it triggers very different categories of measures – short-term disruptions lasting hours or days, for example, require black start, island operation and emergency capacities in the electricity grid, whereas medium- to long-term shortages lasting several months primarily require stockpiling, diversification and contractual safeguards.

Six types of disruption

At the impact level, six types were identified from the country analyses, which are briefly introduced below:

Climate risks (K) include extreme weather, cold spells, droughts and storms. They are firmly embedded in all the countries examined – for instance, in the Swedish RVA tradition, which was originally geared primarily towards storms and frost, or in the EU Regulation on security of gas supply, which stipulates a mandatory extreme temperature scenario.

Technical risks (T) cover failures of individual plants and systems during normal operation, failures of control and market infrastructure, and vulnerabilities in supply chains for critical components. The blackout on the Iberian Peninsula in spring 2025 serves as a reference event.

Global political risks (G) include import disruptions caused by sanctions regimes, targeted supply restrictions, market distortions in tight global markets (war in Iran) and longer-term geopolitical shifts. Lithuania's decoupling from Russia, Poland's geopolitically driven disruption scenarios and Japan's resource diplomacy are examples of responses to these risks.

Asset destruction (A) describes the physical damage to or destruction of critical infrastructure components, such as substations, large transformers, gas storage facilities, LNG terminals, subsea cables or pipelines. The damage to the Balticconnector in October 2023 and the bombing of the Nord Stream pipelines, albeit without any immediate impact on supplies, are examples of this.

Cluster or contagion risks (C) encompass the transmission of a disruption from one system to neighbouring systems – such as cascading failures in energy and telecommunications networks or cross-border effects via interconnected grids. Here, too, the 2025 blackout in Spain is the key reference event.

Social or endogenous risks (S) cover challenges that do not result from exogenous shocks, but from political and social upheavals.

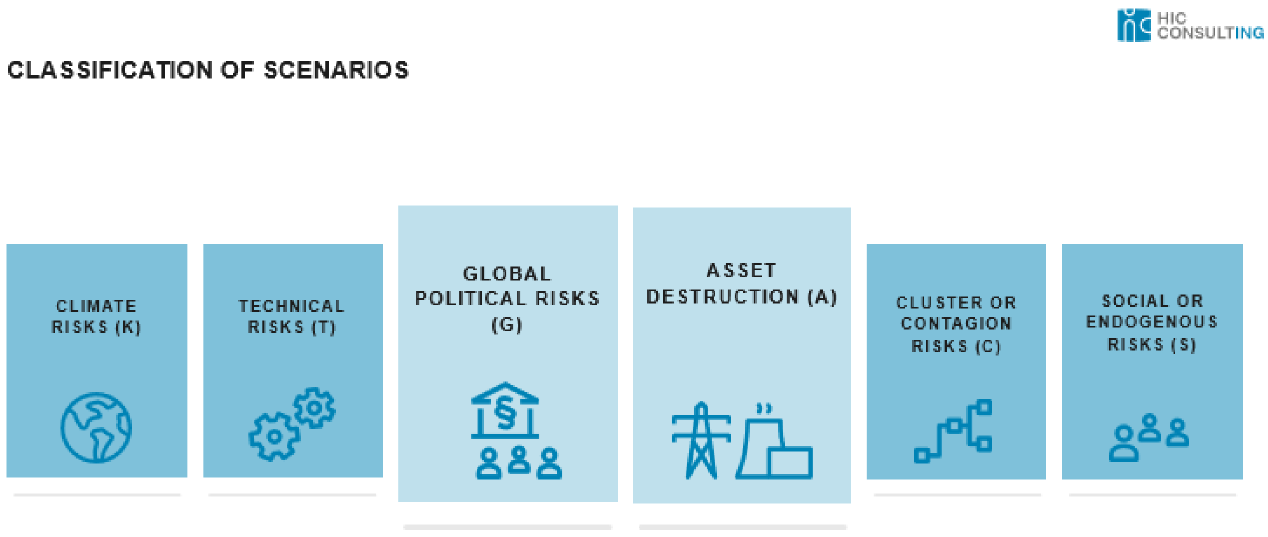

Figure5-1 : Classification of scenarios

From this range of possibilities, the following in-depth analysis focuses on two main types: **G and A**. This focus also reflects the finding that, in the countries examined, it is precisely G and A that have provided the key impetus for the further development of resilience planning. **K** is largely covered in German practice and is treated as a background category. **T** and **C** are treated as **amplifying and escalation dimensions respectively**: they typically do not generate independent patterns of consequences, but rather overlay and amplify the main types. **S** is excluded for methodological reasons, as the consequences of political and social destabilisation of society are very difficult to categorise and its inclusion in this study could lead to arbitrariness.

Type G – Global political disruption scenarios

G1 – Disruption of import routes. This sub-type encompasses the sudden or foreseeable imminent disruption of what is usually a critical import route or supply relationship. In particular, in 2022 Germany had to compensate for the loss of virtually all Russian gas supplies. Poland has explicitly integrated geopolitically driven disruption scenarios into its Preventive Action Plan, thereby systematically differing from German practice. Lithuania carried out its decoupling from the Russian electricity grid – which, whilst strategically planned, was nevertheless implemented very rapidly – for political reasons and, since the cessation of Russian supplies, has been sourcing its gas entirely via the Klaipėda LNG terminal. G1 is characterised by a clear trigger threshold, a short to medium time frame (days to a few months) and a high demand for available substitution capacities in the form of reserves, alternative import routes or domestic production.

G2 – Prolonged geopolitical shortages. Whilst G1 addresses sudden disruptions, G2 describes structural shortages lasting from months to years. These include market distortions caused by sanctions regimes, long-term price shocks, competition for scarce LNG volumes on the world market, geopolitically motivated supply restrictions and conflict-related disruptions such as the de facto blockade of the Strait of Hormuz. Japan's Strategic Energy Plan primarily addresses this type through its resource diplomacy-based safeguarding of long-term contracts and institutionalised fuel stockpiling. The Polish debate on import caps and the

Lithuanian diversification framework should also be understood in this context. The categories of measures for G2 differ significantly from those for G1: they include strategic stockpiling, long-term supplier relationships, regulatory diversification requirements and institutionalised resource diplomacy.

Type A – Asset destruction

A1 – Selective asset destruction. This sub-type covers the destruction or severe damage to individual critical infrastructure components. The damage to the Balticconnector in October 2023, which can also be classified as a G1 case, represents a paradigmatic A1 case because a specific physical asset was the target of the attack and it exposed the vulnerability of offshore infrastructure in the Baltic Sea. Characteristic features include a rapid escalation and a pronounced single-point-of-failure risk. Finnish resilience planning explicitly concludes from observations of the war in Ukraine that the concentration of the generation fleet on a few large units and a centralised transmission grid constitutes the greatest vulnerability. The Swedish approach of targeted island operation can be interpreted as a response to this risk pattern.

A2 – Distributed or coordinated asset destruction. In contrast to A1, this sub-type describes the simultaneous or staggered disabling of multiple assets, often combined with a cyber component or hybrid adversarial control. The threat scenarios against critical infrastructure identified in the UK National Risk Register 2025 and the possibility of hybrid attack patterns taken into account in Finnish planning form the empirical basis here. A2 scenarios are characterised by increased recovery complexity, as it is not a single asset but a network of interdependent assets that is affected. They trigger classes of measures such as island operation and black start capability, redundant supply architectures, and centralised crisis coordination, as identified on multiple occasions in the country analyses.

Cross-cutting dimensions: technology and clusters

As introduced at the outset, T and C are not treated as independent types, but rather as amplifying or escalation dimensions. Cyber-attacks on control systems, failures of SCADA and market infrastructure, and dependencies on critical components in supply chains increase the damage potential of the main types without altering their fundamental sequence of events. Cluster effects – such as the interconnection of energy and telecommunications systems or cascading effects across interconnected networks – typically occur in the course of a G or A event and shape its escalation and recovery profile.

Combination scenarios

The possibility that several of the types described above may occur simultaneously or in a cascading manner – such as a ‘dark lull’ coinciding with a geopolitical escalation – is not treated as a separate type in the classification, but is understood as a methodological requirement for the scenario framework outlined in the following chapter. The framework must be capable of linking individual types with one another, thereby modelling compound events, which often represent the greatest test of resilience for an energy system.

Function of the classification

The typology developed here thus fulfils two functions: it assigns the stress scenarios documented in the country chapters to a grid, and it provides the building blocks for the model scenarios set out in the following chapter. Four model scenarios – two from the G range, two from the A range, with different time dimensions and amplification profiles – subsequently form the basis for comparison with the policy measures and further analysis results in Chapter 6.2.

5.2 Scenario framework for Germany and development of model scenarios

The typology developed in Chapter 5.1 highlights the need to provide a methodological framework with which scenarios can be created from abstract types. The following blueprint fulfils this function. It is not to be understood as prescriptive, but rather as an indicative guide to the approach and can be used both within the study (for comparing the policy measures and further analysis results from Chapter 6.1 with the model scenarios in Chapter 6.2) and, looking ahead, as **a guide for energy companies, planning authorities and political stakeholders**.

The framework draws on international examples: the **Swedish Risk and Vulnerability Analysis** (RVA), which has been established as a standard format for network operators for over ten years; the **Finnish 'Open List'**, which stipulates that preparations must be made for 'everything that is relevant'; and the consolidated catalogue of scenarios set out by the **UK National Risk Register**. Unlike these models, the framework developed here focuses on types G and A, which have tended to be under-represented in German practice to date.

Each scenario is described according to seven parameters:

1. Trigger class. Classification into a type from Chapter 5.1 (G1, G2, A1, A2).

2. System level affected. Generation, transmission network, distribution network, storage, import infrastructure or market infrastructure.

3. Time scale. Hours – days – weeks – months – years.

4. Geographical scope. Local, regional, national or cross-border.

5. Escalation pattern. Sudden (instantaneous failure), gradual (successive shortages/disruptions) or staggered (several events occurring at different times).

6. Amplification profile. Do further disruptive events overlap with or underpin the main event – cyber component, telecommunications failure, cascading effects into other critical sectors?

7. Recovery options. What requirements arise in terms of response and stabilisation, and which category of measures is typically activated?

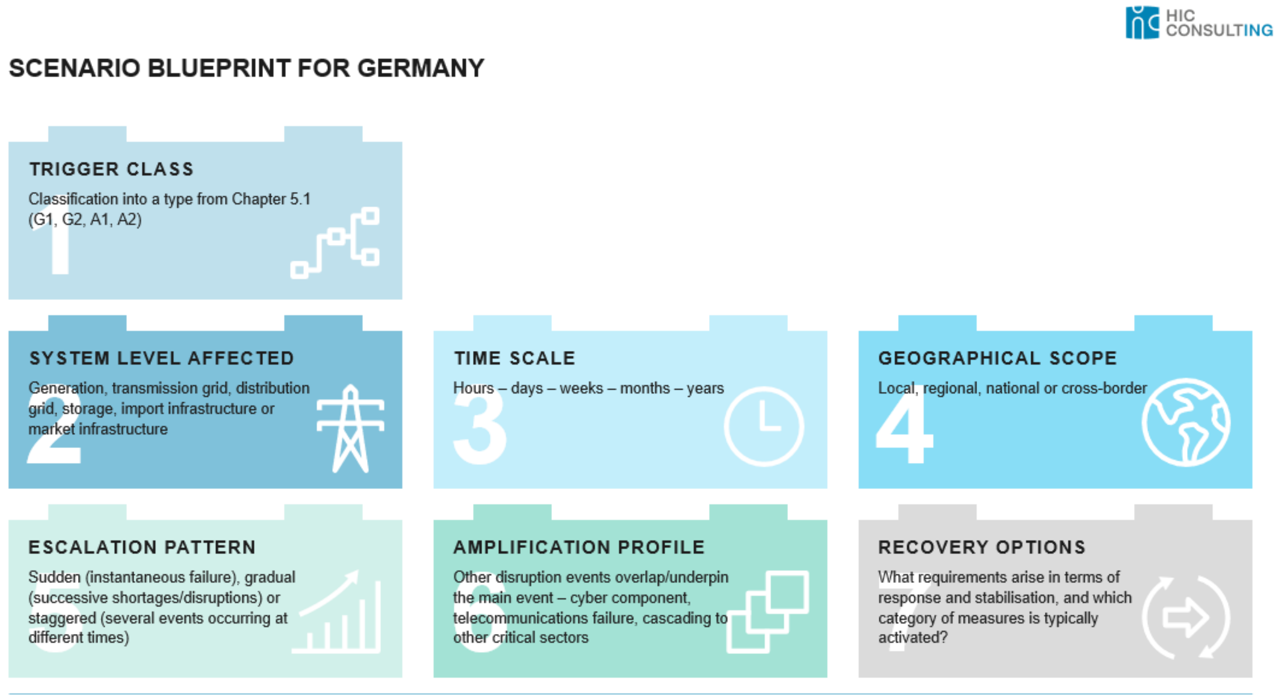

Figure5-2 : Scenario blueprint for Germany

Methodological classification

The four model scenarios presented below are intended as a **guide**, not as an exhaustive list. The model scenarios are not intended to serve as a definitive threat assessment or to derive binding resilience requirements. However, they enable a structured comparison of the measures identified in this study with exemplary stress scenarios. The aim is to draw up a proposal and an initial approach for structured resilience planning.

Four model scenarios for the German context

To categorise scenarios effectively, it seems particularly sensible to structure them according to the type of failure and its duration. On the one hand, a distinction can be made between failures at the commodity level and those at the infrastructure level. On the other hand, differentiating between short-term and long-term failures enables a systematic classification of the impacts and necessary actions. Combining these two dimensions results in a clearly defined categorisation of model scenarios. The following four model scenarios illustrate this differentiation by type of disruption (commodity/infrastructure) and duration (short/long).

M1 – Short-term disruption to an import route during the heating season (commodity disruption / short-term)

Table2 : Model scenario M1

Scenario parameters – M1	
Trigger class	G1 (import route disruption) with extreme weather overlay
System level affected	Import infrastructure, storage, gas-fired generation
Time frame	Acute phase: three to twelve weeks
Geographical scope	National, with implications for European neighbours
Escalation dynamics	Erratic, with a delayed peak in demand due to a cold spell
Amplification profile	Cold spell with a heating load well above average; no significant T or C component
Recovery profile	Activation of strategic reserves, load management, EU solidarity mechanisms, alternative import routes

The scenario is based on the Polish approach, which explicitly addresses such situations in its Preventive Action Plan, as well as on Finland's experience with the Balticconnector. M1 focuses on the resilience of stockpiling, storage availability and short-term load flexibility.

M2 – Prolonged geopolitical supply shortage in the LNG market (commodity disruption / long-term)

Table3 : Model scenario M2

Scenario parameters – M2	
Trigger class	G2 (prolonged geopolitical shortage)
System level affected	Import infrastructure, market infrastructure, gas-fired generation, large industrial consumers
Time frame	12 to 24 months
Geographical scope	Cross-border (global market) with national implications
Escalation dynamics	Gradual, with sporadic sudden escalations
Amplification profile	Secondary effects on industry and district heating; no significant T-component
Recovery profile	Strategic stockpiling, diversification, long-term supplier relationships, resource diplomacy

Based on Japan’s Strategic Energy Plan and its institutionalised fuel stockpiling, as well as the Polish debate on diversification. M2 primarily examines the sustained strain on the supply infrastructure over several heating seasons.

M3 – Attack on maritime infrastructure in the North Sea or Baltic Sea (infrastructure failure / long-term)

Table4 : Model scenario M3

Scenario parameters – M3	
Trigger class	A1 (localised asset destruction), resulting in impacts similar to G1
System level affected	Import infrastructure (pipeline or power cable), transmission grid
Time scale	Acute phase: days to weeks; Recovery: months to years
Geographical scope	Cross-border (North Sea or Baltic Sea), with national implications
Escalation dynamics	Erratic, with long recovery times
Amplifier profile	Geopolitical dimension; possibility of staggered follow-up attacks
Recovery profile	Redundant supply architectures, international repair capacities, activation of reserves during the recovery phase

Based on the Nord Stream attacks in 2022 and the damage to the Balticconnector in October 2023, as well as Finland’s lessons from the war in Ukraine regarding the vulnerability of centralised transmission architectures. M3 primarily tests the resilience of redundancy, replacement capacities and international recovery coordination.

M4 – Coordinated large-scale hybrid attack with a cyber component (infrastructure failure / short)

Table5 : Model scenario M4

Scenario parameters – M4	
Trigger class	A2 (distributed asset destruction) with T and C amplification
System level affected	Transmission and distribution networks, control and market infrastructure, telecommunications
Time scale	Acute phase: hours to days; Stabilisation: weeks
Geographical scope	Regional to national, with potential cross-border cascades
Escalation dynamics	Staggered and cascading (multiple attack vectors at different times)

Amplifier profile	Cyberattack on SCADA, telecommunications failure, possibly accompanied by a parallel disinformation component
Recovery profile	Island operation, black start capability, redundant supply architectures, centralised crisis coordination

This scenario is based on the threat scenarios against critical infrastructure set out in the UK National Risk Register 2025, on the Finnish preparedness concept against hybrid attack patterns, and on the lessons learnt from the Iberian blackout in spring 2025 regarding the interdependence of energy and telecommunications. M4 primarily assesses short-term crisis resilience and the institutional coordination of the response.

5.3 Institutional anchoring

German policymakers and institutions could set themselves the task of developing a national catalogue or register of scenarios. To do so, a decision would first need to be made on the fundamental approach. Three approaches to scenario processes can be broadly classified in the countries examined:

Top-down – the state sets scenarios at a high level; companies implement them. Lithuania and Poland follow this model: the Ministry of Energy or a government representative defines the threats deemed relevant (in both cases with a clear focus on Russia), and state-controlled energy companies respond accordingly.

Bottom-up – the industry plans, whilst the state merely sets the framework. Finland is a prime example of this: the sectoral pools are company-led. Action-relevant scenarios arise primarily from collaboration rather than regulation; the government merely specifies the maximum framework ("be prepared for everything"). Politically, no definitive list is established; the technical risk analysis determines the situations requiring coverage. One of the model's limitations is evident where investments have implications for competition.

Hybrid – the state sets targets, whilst decentralised implementation is institutionalised. Sweden is the clearest example of this: the government defines resilience requirements and typical scenarios; Svenska Kraftnät, as the transmission system operator and emergency response authority, implements these. The association Energiföretagen Sverige is involved on behalf of the industry. The United Kingdom is moving towards a hybrid model recommended by the *National Preparedness Commission*; an *Energy Resilience Strategy* has been announced for 2026.

Three characteristics recur across all three models.

Leadership usually lies with clearly designated institutions, the number of which is manageable. The German model, with responsibilities divided between transmission system operators, the Federal Network Agency (BNetzA), the Federal Ministry for Economic Affairs and Energy (BMWE), security authorities and a crisis coordination centre that meets only in the event of a crisis, is largely an isolated case in this respect. Secondly, the review takes place within clearly defined timeframes, with a fixed **cycle**. Thirdly, **stress scenarios** are systematically incorporated into existing **planning tools**.

6 COURSES OF ACTION

6.1 Policy recommendations and further analysis results from the country analyses

The best-practice elements identified in the six country chapters and in the comparative summary (Chapter 4.8) are set out below in a collection of policy recommendations and further analysis results, structured **according to the four key areas of action** from Chapter 2.3 : Institutional framework and cooperation structures, scenarios and planning tools, strategic reserves and stockpiling, and network and system architecture.

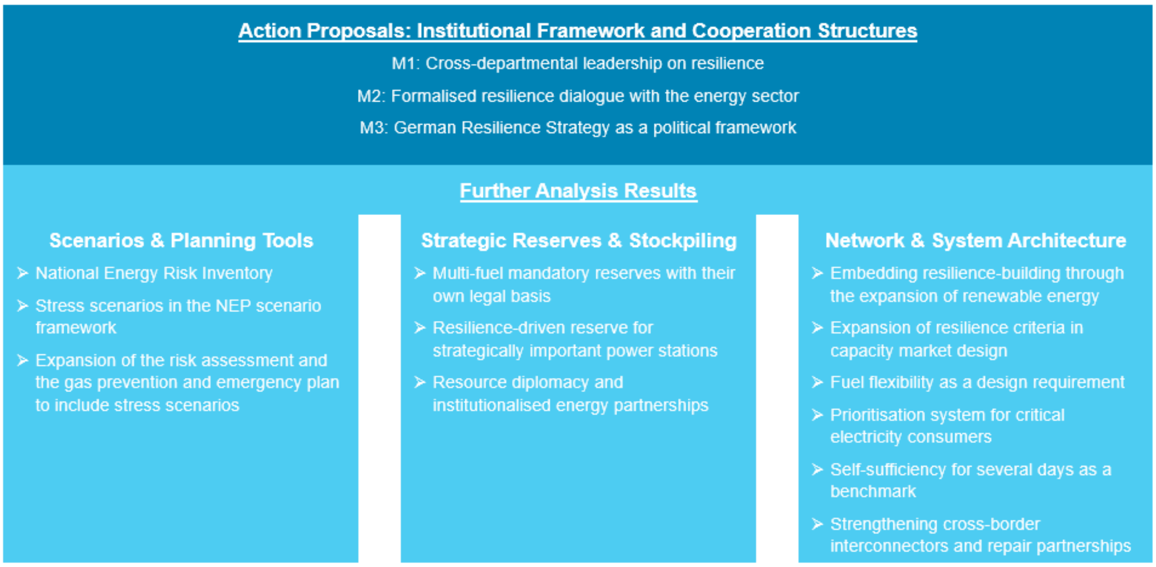

Figure6-1 : Overview of policy recommendations & further analysis results

The proposed measures relating to the **institutional framework and cooperation structures** should be understood as taking precedence over the other analysis results. This means that proposed measures 1 to 3 should be regarded as structural measures, the substance of which is subsequently supplemented by the best practices observed in the three other key areas of action, in the form of further analysis results.

Four further preliminary remarks are important:

Firstly, the collection of policy recommendations and further analysis results is expressly not intended as a detailed implementation plan, but rather as a source of inspiration and a basis for discussion. A detailed examination and formulation of the implementation options would significantly exceed the intended scope of the study.

Secondly: Resilience building blocks already exist, including, amongst other things, the KRITIS umbrella act, the Electricity Risk Prevention Plan, the Gas Prevention Plan, the various types of reserves within the context of the Energy Industry Act (EnWG), and a dense network of associations and crisis management teams. The proposed measures and analysis results should therefore be regarded as catalysts for crucial additions. Should implementation be considered, their compatibility with existing legislative and regulatory frameworks as well as ongoing legislative processes must be assessed, and their practical feasibility and funding must be ensured.

Thirdly, the compilation deliberately omits certain elements contained in the country analyses that were classified as non-priority or non-transferable. These include a complete copy of the Finnish model of a National Emergency Preparedness Agency (NESA equivalent), which is not recommended in view of the existing German structure of associations and authorities. Secondly, a nationwide mandatory model for off-grid operational capability based on the Swedish model (*ödrift*) has been omitted due to the high level of effort involved. Thirdly, radical approaches such as the Lithuanian model of politically driven, far-reaching energy independence are not transferable due to the differences in Germany's starting point, both in terms of scale and structure.

Fourthly, the proposed measures and analysis results are deliberately focused particularly strongly on the national level. Numerous measures could also be tackled within the European framework, but presumably with a longer implementation timeframe and a less clear focus on German circumstances, both in terms of institutional prerequisites and the structure of the energy system.

The collection comprises a total of **3 policy recommendations and further analysis results**, which are presented below across the four key areas of action.

6.1.1 Policy recommendations: Institutional Framework and Cooperation Structures

The comparative analysis has shown that all the countries examined have a central body with clear leadership responsibility and that resilience is enshrined in a high-level political strategy document. By contrast, the German framework features a decentralised structure of responsibilities, in which operational functions (transmission system operators), regulatory functions (BNetzA), political functions (BMWE) and security-related functions (BMI, BBK, security authorities) coexist without any discernible cross-ministerial leadership on resilience. Three policy recommendations arise from this finding.

Action Proposal 1: Cross-departmental leadership on resilience

Table6 : Action Proposal 1

Action Proposal 1	
Proposal	Establishment of a permanent, inter-ministerial lead body for energy resilience with decision-making authority, a steering mandate over subordinate specialist authorities and an interface function with the energy sector. This body, with cross-departmental remit, is based either in the Federal Ministry for Economic Affairs and Energy (BMWE) or the Federal Chancellery.
International examples	In Sweden, Svenska Kraftnät combines the operation of the transmission grid, the electricity emergency authority and the co-financing body for distribution system operators within a single institution. In 2024, Poland established the post of *Government Plenipotentiary for Strategic Energy Infrastructure*, who oversees matters across government departments and assumes a coordinating role in the event of a crisis. In 2024, the United Kingdom established the *National Energy System Operator* (NESO), a system operator institution wholly owned by the public sector .

	Japan coordinates through the METI-ANRE-JOGMEC triad.
German context	The Gas Crisis Coordination Centre, which convenes in the event of a crisis, and comparable structures in the electricity sector are designed to be reactive and are not intended for strategic resilience planning during periods without major disruptions. This measure addresses this gap without establishing a new large-scale authority. It can be set up as an inter-ministerial unit by a resolution of the Federal Government. Should it be implemented, the existing regulations governing the competences of the federal states must be strictly observed.

Action Proposal 2: Formalised resilience dialogue with the energy sector

Table7 : Action Proposal 2

Action Proposal 2	
Proposal	Establishment of a permanent, formalised resilience dialogue between government bodies and the energy sector, going beyond the existing KRITIS working groups, etc. Tasks include the structured exchange of (including classified) situational assessments, the joint preparation and conduct of exercises, and annual gap analysis and status reporting. The sector will be institutionally integrated via existing association structures.
International examples	Finland’s sector pools are public-private cooperation structures that have evolved over several decades. Japan’s METI and ANRE operate through permanent working groups within the energy industry, in which a committee comprising the ten largest electricity producers and the Council for Transmission and Distribution Networks advises METI.
German context	Existing association and working group structures (KRITIS working groups, sectoral crisis management teams) already fulfil parts of the dialogue function. The added value stems from three aspects: institutionalised access to situational assessments, regular

	rather than ad hoc engagement, and, crucially, clear lines of responsibility in the event of a crisis.

Action Proposal 3: German Resilience Strategy as a political framework

Table8 : Action Proposal 3

Action Proposal 3	
Proposal	Adoption of an inter-ministerial, high-level resilience strategy that establishes resilience as an objective on a par with decarbonisation and cost-efficiency (by broadening the so far narrowly defined or implemented objective of security of supply) and provides a reference framework for planning instruments. The strategy sets out protection objectives, timeframes and endurance requirements at a level of abstraction that is compatible with the plans and capabilities of lower levels of government.
International examples	Finland's *'kokonaisturvallisuus'* (concept of comprehensive security) and the complementary establishment of a *National Preparedness Commission*; Japan's *Strategic Energy Plan* and Lithuania's *National Energy Independence Strategy*. China's Five-Year Plan, adopted in March 2026, is also instructive in this regard, as it significantly reinforces technological, economic and energy policy resilience as a guiding principle across all government departments.
German context	No comparable energy-related resilience strategy has been established to date. Individual building blocks do exist – the KRITIS Framework Act (physical security), the NIS 2 implementation (cybersecurity), the National Security Strategy 2023 (overarching) – but these are fragmented across sectors and do not contain an integrated resilience strategy for the energy sector. This measure closes this gap.

6.1.2 Further Analysis Results: Scenarios and Planning tools

All the countries examined have an institutionalised scenario-planning process with a fixed cycle, designated lead departments and regular updates to the national risk profile – although this is generally not consistently centralised. Stress scenarios are mandatorily integrated into planning tools in several countries. In Germany, this integration has so far only been partially implemented.

National Energy Risk Inventory

Description: Publication of a consolidated, regularly updated national risk inventory for the energy infrastructure by an appropriate government body. The inventory records the risks classified as relevant, including their trigger class, escalation dynamics and a description of the reasonable worst-case scenario, and serves as the reference point for downstream planning tools. The risk inventory should be evaluated and updated at short, fixed intervals (e.g. annually).

International examples: The *UK National Risk Register 2025* lists 89 risks across nine thematic areas, each with *a* detailed *'reasonable worst-case scenario*'. The Finnish Security Committee's national risk assessment is updated at regular intervals (most recently in 2023). Sweden works with consolidated *scenario types*, which are incorporated into regional risk and vulnerability analyses.

Stress scenarios in the NEP scenario framework

Description: Examination of an extension to the scenario framework for electricity and gas network development planning (NEP Electricity and Gas/Hydrogen) to include stress scenarios, involving the TSOs, network operators and the relevant regulatory authorities. Particular attention should be paid to the stress scenarios 'import route failure' (Type G), 'destruction of critical transmission infrastructure' (Type A) and 'coordinated hybrid attack patterns' (Type A with an amplification profile).

International examples: The *Future Energy Scenarios* published annually by the UK's *National Energy System Operator* (NESO) incorporate stress scenarios. The *UK National Preparedness Commission* has explicitly recommended the mandatory integration of stress scenarios into energy infrastructure planning by 2025. Poland's *Preventive Action Plan,* drawn up in accordance with EU Regulation 2017/1938, incorporates geopolitically driven disruption scenarios under the risk groups Belarus and Ukraine.

Expansion of the risk assessment and the Gas Prevention and Emergency Plan to include stress scenarios

Description: Extension of the three gas instruments required under EU Regulation 2017/1938 – the BNetzA's national risk assessment (Article 7), the Gas Prevention Plan (Article 9, BMWE) and the Gas Emergency Plan (Article 10, BMWE) – to include stress scenarios that go beyond the disruption to Russian supplies experienced in 2022: prolonged LNG market disruptions, attacks on offshore infrastructure and hybrid escalation patterns. These should be continuously updated.

International examples: Poland explicitly integrates geopolitically driven disruption scenarios into its *Preventive Action Plan* under the risk groups 'Belarus' and 'Ukraine', thereby utilising the risk-group logic laid down in the SoS Regulation. Japan's Strategic Energy Plan primarily addresses the type of prolonged geopolitical shortage (G2) through resource diplomacy and institutionalised fuel stockpiling. Finland takes hybrid threat patterns into account as an amplifying factor in its national risk assessment.

6.1.3 Further Analysis Results: Strategic Reserves and Stockpiling

Three recurring findings from the country analyses characterise this area of action. Firstly: the countries examined systematically exceed the EU minimum standard in their stockpiling, in some cases with their own legal basis. Secondly: stockpiling is increasingly being designed to cover multiple energy sources, with a government agency acting as the implementing body. Thirdly: Reserves with a rationale explicitly driven by civil protection and resilience – as opposed to reserves justified on the grounds of market, grid or climate policy – have their own legal basis in the countries under comparison and are institutionally distinct from other types of reserves.

Multi-fuel mandatory reserves with their own legal basis

Description: Introduction of a cross-fuel mandatory reserve with its own legal basis, which goes beyond the EU minimum requirements and covers all energy sources relevant to security of supply – oil and oil derivatives, natural gas and LNG, lignite, hard coal and, in the future, hydrogen. Responsibility for building up and managing the reserve lies with a government agency or an existing body to be mandated for this purpose.

International examples: Poland's *Act on Stocks* obliged sellers or end users importing natural gas to maintain stocks covering 30 days' worth of imports, which must be deliverable to the Polish gas system within 40 days. The Polish *Government Strategic Reserves Agency* (RARS) is responsible for centralised management; a reform aimed at greater centralisation within the RARS has been underway since 2025. Finland's *Huoltovarmuuskeskus* (NESA) operates a two-pillar stockpiling model comprising state reserves and mandatory corporate stockpiling under the Security of Supply Act.

Resilience-driven reserve for strategically important power stations

Description: Creation of a form of reserve explicitly driven by civil protection and resilience for strategically important power station capacity. Selection criteria, activation logic and funding are regulated separately; institutional placement is linked to inter-ministerial leadership (Action Proposal 1).

International examples: Finland has contractually reserved its remaining coal-fired power station, Meri-Pori, for crisis situations. NESA is responsible for this reservation, which is independent of market-based or grid-related reserves. Israel, moreover, maintains its coal-fired power stations in continuous maintenance mode as a strategic reserve for emergencies, so that they can be made operational again at short notice. The Finnish example demonstrates that such a form of reserve can be established within the existing EU framework (in particular state aid assessment).

Resource diplomacy and institutionalised energy partnerships

Description: Establishment of institutionalised resource diplomacy to secure long-term supply relationships for natural gas and LNG, and, in the longer term, for hydrogen and hydrogen derivatives. The core element is the provision of diplomatic support at the highest level for German importers in supplier countries and the consolidation of energy partnership agreements within a specifically mandated structure.

International examples: Japan's institutional triangle of METI-ANRE-JOGMEC organises resource diplomacy in a systematic and institutionalised manner; the *Japan Organisation for Metals and Energy Security* (JOGMEC) provides a particularly illustrative reference in this regard. The Polish and Lithuanian diversification initiatives (Świnoujście LNG terminal, Gdańsk FSRU, Baltic Pipe, Klaipėda LNG terminal) are also examples of state-led diversification.

6.1.4 Further Analysis Results: Network and System Architecture

The country analyses have yielded less consistent findings in this policy area than in the other three: energy networks and generation structures are shaped by the respective geographical, geopolitical and historical circumstances. However, four fundamental principles that recur in the country findings are transferable: the strategic prioritisation of decentralised generation, the prioritisation of socially important electricity consumers in crisis situations, a self-sufficiency target at distribution level, and the strengthening of cross-border redundancy.

Embedding resilience-building through the expansion of renewable energy

Description: Enshrining increased resilience as an equally valid justification for the expansion of renewable energy generation alongside climate and industrial policy: Firstly, the explicit enshrinement of the resilience rationale in the relevant standards and other policy instruments. Secondly, steering towards consumption-proximate and distributed generation through a differentiated incentive structure. The measure is not primarily aimed at accelerating the already high planned rate of expansion, but rather at providing an updated and thus strengthened argumentative and normative basis.

International examples: The observation that non-fossil, import-independent generation is itself a factor in resilience is particularly evident in the Nordic countries: Finland and Sweden possess structural resilience stemming from their independence from imports. Both rely in particular on renewable energy and nuclear power for this purpose. Finnish resilience planning also explicitly concludes from the war in Ukraine that the concentration of the generation fleet on a few large units represents the greatest systemic vulnerability. Japan's 7th *Strategic Energy Plan* explicitly justifies the expansion of renewable energy as the 'main power source' – with an investment programme of around one trillion US dollars over ten years – on the grounds of security of supply and resilience, and identifies storage batteries and aggregators as decentralised resilience tools. *The* UK's *Energy Resilience Strategy,* announced for 2026, brings together the sustainability transition and resilience. China's 15th Five-Year Plan justifies the expansion of wind, solar, hydro and nuclear power primarily with the aim of reducing dependence on imports, not with climate protection. Lithuania's *National Energy Independence Strategy* explicitly places climate neutrality and energy independence on an equal footing. Israel addresses the spatial logic of resilience through a mandatory solar roof scheme for new residential buildings and certain non-residential buildings, as well as through a differentiated feed-in tariff system that pays higher rates for rooftop PV in urban areas with more than 50,000 inhabitants, thereby incentivising generation close to the point of consumption. Finally, the experiences in Ukraine confirm that, in the event of a crisis, decentralised and distributed generation capacities offer a resilience advantage over centralised large-scale units.

Expansion of resilience criteria in capacity market design

Description: Expansion of the resilience criteria in capacity market design to include aspects such as decentralisation, black-start capability, fuel flexibility and geographical distribution. The aim is to give decentralised generators and storage facilities greater prominence compared to centralised large-scale units, without overshadowing other criteria (e.g. long-term capacity, regional component).

International examples: Finland does not implement distributed generation through direct subsidies for distributed generation facilities, but rather through three indirect mechanisms, including a regulatory requirement within the distribution network. Finnish resilience planning explicitly concludes from observations of the war in Ukraine that a reliance on large power units and a centralised transmission grid represents the greatest systemic vulnerability. However, Finland does not have a capacity market in the German sense.

Generation-side management is handled via the tender-based Non-Fossil Flexibility Support Scheme. Embedding resilience criteria into a capacity market design would therefore represent a further development of this approach.

Fuel flexibility as a design requirement

Description: Inclusion of fuel flexibility – specifically: the ability to operate not only on natural gas but also on a liquid secondary fuel (typically heating oil, and possibly green fuels in the future) – as a criterion in the capacity market design and in the funding conditions for strategically important existing plants. The measure is not intended as a general requirement for the entire plant fleet, but rather as an incentive structure based on the systemic importance of the respective plant.

International examples: Israel requires power stations to be dual-fuel capable; most Israeli power stations are accordingly equipped to use a liquid secondary fuel (predominantly diesel). This requirement is enforced via the operating licence. Plants that do not meet the resilience standards are not granted an operating licence. The background to this is the vulnerability of Israel's gas supply (supplied via just two pipelines from offshore fields, with no national gas storage). Finland applies a similar approach to district heating CHP: plants typically have multi-fuel capability and thus contribute to a redundant supply structure. Japan addresses the same issue by combining gas and coal in electricity generation, with the storability of coal explicitly cited as a resilience argument.

Prioritisation system for critical electricity consumers

Description: Explore, together with member companies, federal states and local authorities, the establishment of a prioritisation system for critical electricity consumers in crisis situations. The system would come into effect below the threshold for the emergency regime and could thus complement existing energy sector regulations, although issues of equitable supply, responsibilities and legal bases would need to be clarified in advance.

International examples: The Swedish Styrel system, originally introduced in the 1970s in response to the oil crisis and further developed on several occasions since then, organises prioritisation through a combination of a central methodology (Svenska Kraftnät) and regional implementation (Länsstyrelser, distribution system operators). In the expert discussion, Styrel was identified as one of the key foundations for resilient crisis management, with room for improvement in its integration with the overarching crisis management system.

Self-sufficiency for several days as a benchmark

Description: The establishment of a specific self-sufficiency target (e.g. lasting several days) for distribution networks as a framework for local authority crisis preparedness in the electricity, gas and heating sectors should be discussed as a guiding principle. This could help to translate the abstract resilience target into operational requirements for energy suppliers, hospitals, drinking water supply, heat supply and other areas of essential public services, as well as parts of critical infrastructure. However, its specific implementation requires further clarification regarding responsibilities, technical prerequisites and funding.

International examples: The Swedish self-preparedness rule forms part of the total defence concept and is aimed at households, workplaces and critical infrastructure operators. Finland works with a shorter target timeframe of between a few days and a week, embedded within the kokonaisturvallisuus model.

Strengthening cross-border interconnectors and repair partnerships

Description: Targeted strengthening of cross-border interconnectors – electricity and gas – to enhance resilience and establish formalised repair cooperation arrangements for critical infrastructure components. This measure links investment decisions with repair capacity planning at European and Northern European level. Network planning, European cooperation, repair capacities and cost recognition can only be fully assessed in consultation with the TSOs and relevant authorities.

International examples: The Nordic transmission system operators Fingrid, Svenska Kraftnät, Statnett and Energinet cooperate via *NordBER* and bilateral agreements, specifically in the area of crisis preparedness. This includes joint stockpiles, repair capacities and exercises. Lithuania's construction of several interconnectors (NordBalt to Sweden, LitPol Link to Poland, the GIPL gas pipeline to Poland) and the synchronisation of the Baltic electricity grid with the continental European grid are designed as key resilience measures. Poland, Lithuania, Estonia and Latvia have agreed on a joint plan to protect the electricity grids. Within this framework, Lithuania has announced the establishment of an emergency and crisis reserve for key grid components.

6.2 Alignment of policy recommendations and further analysis results with four sample scenarios

The following sections reflect the portfolio of policy recommendations and further analysis results from Chapter 6.1 against the four model scenarios developed in 5.2. The aim is not to conduct an exhaustive examination of each course for action and further analysis result in every scenario, but rather to identify the key aspects in each case. The discussion is qualitative in nature and identifies three to five key aspects for each scenario, followed by a brief classification of other relevant policy measures and analysis results. References to the three action proposals from 6.1 are made using their numbering; M1 to M4, on the other hand, stand for the four model scenarios.

Model scenario M1: Short-term disruption to an import route during the heating season (commodity disruption / short-term)

Model scenario M1 describes a sudden disruption to a critical import route lasting between three and twelve weeks, coinciding with a pronounced cold spell with above-average heating demand. The objectives are the rapid mobilisation of reserves and alternative import routes, as well as demand management where necessary.

The **key analysis findings** for Scenario M1 include the following:

- Mandatory reserves across all energy sources with their own legal basis
- Expansion of the risk assessment and the Gas Prevention and Emergency Plan to include stress scenarios
- Resource diplomacy and institutionalised energy partnerships
- Strengthening cross-border interconnectors and repair cooperation

Mandatory reserves across different energy sources are particularly effective in this context. Stockpiling that exceeds the EU's minimum requirements – particularly in the gas sector and for secondary fuels – is designed precisely for this type of scenario; a disruption to imports lasting several weeks cannot be offset without substantial reserves. This is complemented by the expansion of the risk assessment and the Gas Prevention and Emergency Plan to include stress scenarios. Finally, resource diplomacy and institutionalised energy partnerships have an impact on the procurement side by facilitating the mobilisation of alternative supplies through established partnerships.

Strengthening cross-border interconnectors and repair cooperation ensures physical substitution via alternative supply routes. This is less crucial for Germany in the electricity sector, as the European interconnected network already exists; in the gas sector, however, it takes on its own significance through the combination of pipeline connections and LNG import capacities.

Of secondary importance are a prioritisation system for socially critical consumers and a target level for self-sufficiency. Staged load shedding or decentralised contingency capacity only come into play in the event of further escalation. Interdepartmental leadership on resilience (Action Proposal 1) enables centralised and rigorous coordination. The other institutional measures (Action Proposals 2 and 3) serve to prepare for Scenario M1.

Model scenario M2: Prolonged geopolitical supply shortage in the LNG market (commodity failure / long-term)

Rather than a brief supply disruption, Model Scenario M2 describes a shortage lasting between twelve and twenty-four months, with periodic escalations. Strategic reserves cannot compensate for the entire period – structural adjustments are necessary as part of the response.

The **key analysis findings** for Scenario M2 include the following:

- Resource diplomacy and institutionalised energy partnerships
- Strengthening resilience through the expansion of renewable energy
- Mandatory reserves across all energy sources with their own legal basis

Resource diplomacy and institutionalised energy partnerships are central to this. Institutionalised safeguards for long-term supply relationships stabilise import volumes, particularly in the event of market failure. The Japanese model, with its METI-ANRE-JOGMEC triangle, demonstrates how state equity participation and credit guarantees can provide private companies with a more predictable market position. Strengthening resilience through the expansion of renewable energy has a parallel effect on the structural demand side: any additional fossil-free generation capacity reduces potential price and supply shocks.

Mandatory reserves across different energy sources act as a bridge. Substantial stockpiling can cushion the initial quarters of a shortage and creates the negotiating leeway within which resource diplomacy can take effect.

A resilience-driven reserve for strategically important power stations and fuel flexibility have an impact on the generation side. They enable a switch to secondary fuels or the activation of existing power stations with built-in resilience, thereby reducing electricity generation’s dependence on LNG, which may be in short supply. Both are secondary in the M2 reference scenario because they cover only a subset of the supply architecture, but they gain in importance if the market shortage escalates into a severe electricity supply crisis. The inclusion of stress scenarios in the risk assessment and in the gas prevention and emergency plan remains relevant, but is less central in model scenario M2 than in model scenario M1, as it primarily addresses short-term, acute supply situations rather than multi-year market adjustments.

Model scenario M3: Attack on offshore infrastructure in the North Sea or Baltic Sea (infrastructure failure / long-term)

Model scenario M3 describes the targeted destruction of a key infrastructure component – a pipeline, a subsea cable or an offshore converter platform – with a rapid escalation and a recovery time potentially spanning several years.

The **key analysis findings** for Scenario M3 include the following:

- Strengthening cross-border interconnectors and repair cooperation
- Expansion of resilience criteria in capacity market design
- Strengthening resilience through the expansion of renewable energy
- Resilience-driven reserve for strategically important power stations

Strengthening cross-border interconnectors and repair cooperation plays a key role in this case. It has a twofold effect: through the diversified grid structure, it reduces dependence on a single route, and through repair cooperation – modelled on the Nordic transmission system operators – it shortens the restoration time. Both factors come into play in the M3 reference scenario, as the individual plant cannot be replaced within a matter of weeks.

The expansion of resilience criteria in the capacity market design and the strengthening of resilience through the expansion of renewable energy reduce the single-point-of-failure risk: the emphasis on decentralisation, black-start capability and geographical distribution in the tender design has a positive effect here. If a single large-scale plant or a critical transmission line fails, the consequences can be better mitigated in a more decentralised system.

The resilience-driven reserve for strategically important power stations comes into play during the recovery phase. A civil defence-based generation reserve, modelled on Meri-Pori or Öresundsverket, can be activated whilst repairs are underway.

Stress scenarios within the NEP scenario framework are of secondary importance: taking stress scenarios into account proactively in grid planning would be a prerequisite for incorporating the redundancy required in model scenario M3. A National Energy Risk Inventory and inter-ministerial leadership on resilience (Action Proposal 1) play a preparatory and coordinating role, respectively, in Model Scenario M3.

Model scenario M4: Coordinated large-scale hybrid attack with a cyber component (infrastructure failure / short-term)

In Model Scenario M4, several staggered attacks – physical, cyber and, where applicable, communications-based – strike the energy system simultaneously or in a cascading manner, over a timeframe ranging from hours to days.

The **key analysis findings** for Model Scenario M4 include the following:

- Cross-departmental leadership on resilience (Action Proposal 1)
- Prioritisation system for critical electricity consumers
- Self-sufficiency for several days as the target
- Resilience-driven reserve for strategically important power stations
- Expansion of resilience criteria in capacity market design

Interdepartmental leadership on resilience (Action Proposal 1) is central here. Without coordination that has been well-rehearsed in peacetime, a rapid response to a coordinated hybrid attack is not possible. Experience from the 2025 Spain blackout shows that institutional friction can cost hours or even days.

A prioritisation system for critical electricity consumers plays a particularly important role in the M4 reference scenario, as a full restoration is unlikely to be possible during the acute phase. The priority supply of socially critical consumers – hospitals, waterworks, communications infrastructure – is then particularly crucial. A self-sufficiency target spanning several days prevents some of the societal damage in the event of a severe attack.

A resilience-driven reserve for strategically important power stations and an expansion of the resilience criteria in the capacity market design have an impact via black start and island operation capabilities. Both are central components of technical restoration in the M4 model scenario.

Of secondary importance is a formalised resilience dialogue with the energy sector (Action Proposal 2): the communication channels with the sector, which are practised in peacetime, are a prerequisite for a coordinated response in the M4 reference scenario. A National Energy Risk Inventory and stress scenarios within the NEP scenario framework play a preparatory role, as they are what classify M4-like scenarios as relevant for planning in the first place.

Cross-cutting finding

A small number of policy initiatives and further analysis results have a significant impact across several scenarios – in particular the institutional action proposals 'Inter-ministerial leadership on resilience' (Action Proposal 1) and 'Formalised resilience dialogue with the energy sector' (Action Proposal 2), the analytical groundwork 'National Energy Risk Inventory' and 'Stress Scenarios within the NEP Scenario Framework', as well as the structural generation measure 'Strengthening resilience through renewable energy expansion'. These form a kind of basic resilience framework.

Secondly: Other analysis results are more scenario-specific – resource diplomacy and institutionalised energy partnerships are primarily effective in the M2 reference scenario; fuel flexibility in the M1 and M2 reference scenarios; and the prioritisation system for critical electricity consumers in the M4 reference scenario. Mandatory cross-fuel reserves feature in several scenarios, but fulfil different functions in each case – short-term substitution in scenario M1, and a bridging function in scenario M2.

Overall, the analysis shows that comprehensive resilience planning consists of a combination of specific policy measures, which can be derived from the scenarios, and a comprehensive institutional framework.

7 CONCLUSION AND OUTLOOK

None of the countries examined in this study has a strategic resilience plan that is comprehensive in all respects and could be adopted as a complete model in the German context. However, the country-specific findings enable the identification of courses of action to address the **gaps in the German energy resilience strategy**. These gaps include the concentration of resilience obligations at the operator level, the fragmentation of political and administrative leadership, restrictions on stockpiling, and the near-total absence of stress scenarios in the relevant planning instruments.

Four findings are worth highlighting: Firstly, the analytical distinction between **the operational and strategic levels of resilience**. In the areas of physical plant security, cyber resilience, incident management and reporting obligations, Germany has a legal framework – including the KRITIS Framework Act, the NIS 2 Implementation Act and the regulatory requirements for network operators – which, despite remaining challenges, could be assessed as adequate.

At the strategic level – that is, the integration of resilience criteria into planning tools such as grid development planning, system development strategy, reserve mechanisms and funding schemes – the key instruments are predominantly geared towards normal operation and efficiency targets. The enormous investments in the transformation of the German energy system over the coming decades provide an opportunity to incorporate resilience more strongly into planning.

Secondly: Global political disruptions, in particular disruptions to import routes and prolonged geopolitical market shortages, as well as the targeted destruction of critical infrastructure – notably pipelines, subsea cables, large transformers and LNG terminals – are currently **scarcely covered at a strategic level**, as the development of model scenarios has highlighted. New resilience planning tools can have a particularly significant impact in this very area.

Thirdly, a **fundamental problem of demarcation** is evident: in stress situations falling short of a full-blown crisis, neither market mechanisms function fully nor can emergency instruments be lawfully activated. This gap has not been conclusively closed in the countries under comparison either, though it is at least partially addressed there by intermediate policy measures.

Fourthly, the study shows that greater consideration of resilience in energy system governance is often only made possible by **catalysts**: In the countries examined, strategic resilience reforms were predominantly initiated following specific events, namely the Balticconnector incident and NATO accession in the case of Finland, the North Hyde incident in the case of the United Kingdom, the 2011 earthquake in the case of Japan, following the 2014 annexation of Crimea in the case of Lithuania, and following the first Russian gas dispute in 2006 in the case of Poland. Empirically, reform windows are more frequently opened by shocks than by abstract threat analyses. For the German context, this implies that the **reform window that has existed since 2022** – and which has recently been opened even wider by the blockade of the Strait of Hormuz – should be utilised.

In accordance with the terms of reference, this study has analysed the political and regulatory frameworks. In all six country chapters, the **actors in the energy sector** emerge as independent drivers of resilience and should therefore be considered separately in the conclusion.

Three observations are worth highlighting:

Firstly, in none of the countries under comparison is the relationship between the state and the energy sector organised in a purely hierarchical or purely market-based manner; rather, it is governed by **institutionalised and permanently established cooperation structures**. The Finnish sector pool under the umbrella of NESA serves as the reference case here; comparable functions are fulfilled by the Swedish industry association Energiföretagen Sverige under Svenska Kraftnät, the industry committee of the ten largest electricity producers at Japan's METI, and the Resilience and Emergency Management Unit at NESO. These structures combine operational industry expertise with strategic state responsibility. The German landscape of associations, crisis management teams and KRITIS bodies fulfils some of these functions but, by comparison, exhibits a lower degree of institutionalisation. A formalised, permanent **resilience dialogue** (Action Proposal 2) addresses this gap.

Secondly, there are empirically **demonstrable limits to the voluntary approach**. The Finnish findings show that the pool system works as long as the required investment in preparedness capacity remains low. Where individual companies bear the actual, unreimbursed costs of crisis-related services without their competitors incurring comparable expenses, the sustainability of the voluntary solution is limited. Resilience assets with probabilities of occurrence below the thresholds typically taken into account in business are, as a rule, 'under-produced' in competitive markets. The Swedish solution – regulatory obligations and co-financing combined under one body, Svenska Kraftnät – represents a possible answer, but one that would, in many countries, represent a break with the established relationship between the state and the energy sector.

Thirdly, a category of resilience measures can be identified whose delivery remains particularly closely tied to the **corporate level**. These include black start capability and island operation capability as technical characteristics of individual plants, fuel flexibility as a design decision relating to plant construction, as well as the stockpiling of spare parts, trained repair personnel and a standardised component nomenclature, all of which are maintained in the grid operators' workshops and warehouses. Cooperation between Nordic transmission system operators demonstrates that repair times for critical large components can be significantly reduced through inter-company coordination. The political level can set framework conditions, incentives and obligations, but **responsibility for implementation remains with the companies**.

The proposed measures and further analysis results indicate varying **speeds of implementation**. Proposals 1 to 3 (inter-ministerial leadership, resilience dialogue, resilience strategy) and the further analysis results – the risk inventory, expansion of the NEP scenario frameworks and adaptation of gas-related instruments – can predominantly be implemented through government and administrative decisions and form the analytical and institutional basis for the further analysis results. Cross-fuel mandatory reserves, resilience-driven power station reserves and the prioritisation system require greater effort to implement due to their potential for conflict with climate protection policy objectives and the federal budget.

Finally, an international comparison allows us to draw a **conclusion regarding the approach**: **incremental, individual decisions** taken over longer periods have proved more effective than single, comprehensive reform measures. Poland's diversification of its gas supply spanned around sixteen years; the Finnish pool system has developed over several decades; and the foundations of the Swedish Styrel system date back to the 1970s. Strengthening resilience in Germany should therefore be conceived **as a long-term project spanning several parliamentary terms**, with the aim of establishing its institutional and conceptual framework within the current parliamentary term. **Resilience requires a fundamental consensus across society, political parties and stakeholders**, as well as staying power. It must also be borne in mind that, in the German context, market mechanisms and corporate responsibility are key sources of resilience and form the basis on which any further development of resilience initiatives should be built.

8 LIST OF FIGURES

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