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Climate change preparedness of the Czech energy infrastructure

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Introduction

Energy infrastructure is one of the most important parts of a state's critical infrastructure. Its reliable operation is essential for the functioning of industry, transport, healthcare, water supply and most other services on which modern society depends. The ability of energy systems to withstand emergencies and quickly restore operation following such events is therefore one of the basic prerequisites for energy security.

Climate change brings new challenges in the form of more frequent and intense climatic phenomena. These can limit electricity production, damage transmission and distribution networks and complicate the restoration of energy supplies after emergencies.

The Czech energy sector is already responding to these challenges with a number of adaptation measures, from the modernization of power plants and networks to strengthening crisis preparedness and integrating climate risks into strategic planning. However, the question remains whether the pace of these changes corresponds to the speed at which climate conditions are changing. The following text therefore attempts to provide an overview of the level of preparedness of the Czech energy infrastructure for the impacts of climate change, the main risks and the possibilities for managing them.

The relationship between energy and climate

Electricity and heat production represent the largest source of anthropogenic greenhouse gases, both in Czechia[1] and globally[2]. They thus contribute significantly to human-induced climate change.

However, the relationship between energy and climate change is two-way - an increase in average temperatures also brings an increased incidence of extreme climate events that can threaten the operation of energy infrastructure.

In the Czech Republic itself, the average annual temperature has increased by 2.3 °C over just the last six decades.[3] This increase is roughly double the global average, a pattern seen across all of Europe. Since the mid-1990s temperatures in Europe have been increasing at a rate of more than 0.5°C per decade.[4]

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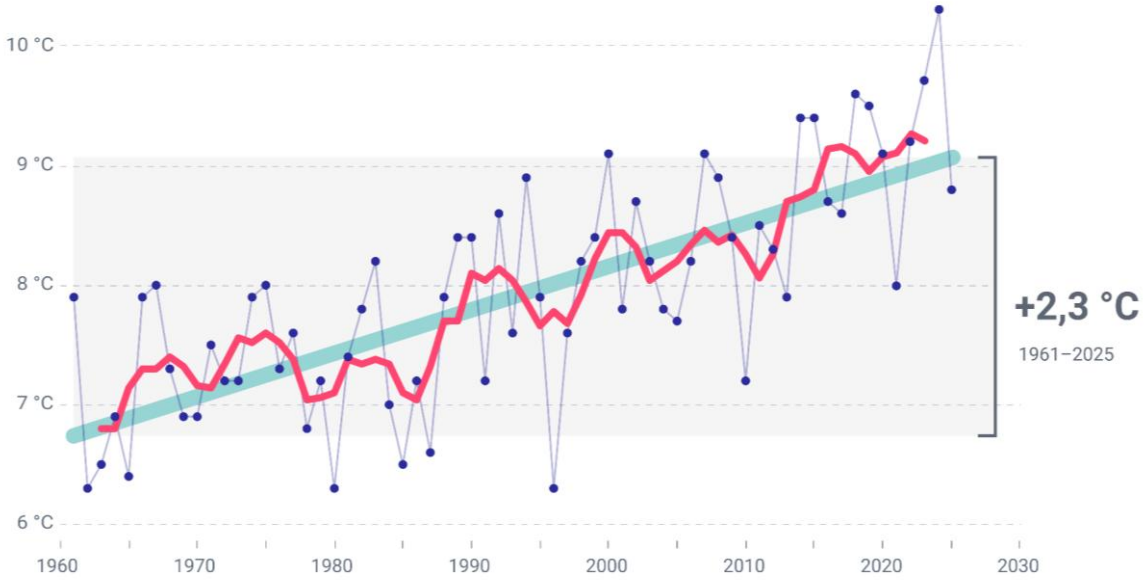
[1] Facts on Climate Change, Greenhouse gas emissions in the Czech Republic by sector, https://faktaoklimatu.cz/infografiky/emise-cr

[2] Our World in Data: Greenhouse gas emissions by sector, World, https://ourworldindata.org/grapher/ghg-emissions-by-sector

[3] Facts on Climate Change: Average annual temperature in the Czech Republic , https://faktaoklimatu.cz/infografiky/teplota-cr

[4] In general, land is warming faster than the ocean, and the Northern Hemisphere is warming faster than the Southern Hemisphere. A more detailed description of the causes of Europe's rapid warming is described here, for example: https://climate.copernicus.eu/esotc/2025/why-europe-warming-so-quickly

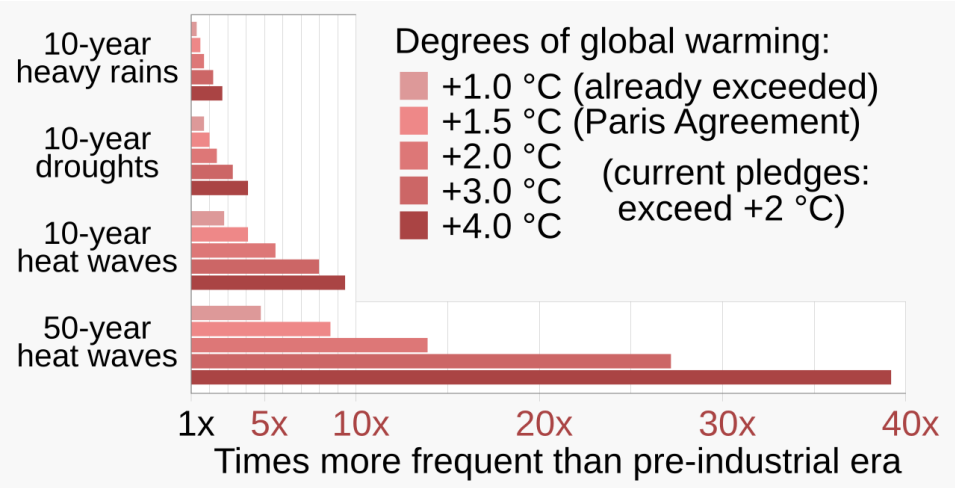
Figure 1: The average annual temperature in the Czech Republic has increased by 2.3 °C since 1961



Source: Facts on Climate Change

At the same time, with each additional degree of warming, the probability and frequency of certain extreme weather events increases non-linearly and in some cases very sharply (see Figure 2).

Figure 2: Frequency of extreme weather for different degrees of global warming



Source: IPCC

From the point of view of energy infrastructure, the potential impacts of these phenomena on electricity systems are crucial. Their functioning affects, among other things, the operation of other parts of the energy infrastructure, such as the supply of heat, cooling, and fuels.

Weather-related phenomena that can affect the operation of the electricity system include:

- heat waves
- drought
- wind gusts
- floods
- icing

Heat waves

Heat waves are characterized as periods of prolonged (usually five or more days) extremely hot weather. High temperatures can pose a dual problem for the electricity system. On the one hand, they increase the demand for electricity and, at the same time, they can limit the availability of certain sources and grid infrastructure.

Impact on electricity consumption

In the Czech Republic, the maximum electricity consumption still occurs during the winter months.[5] However, locally, especially in large agglomerations where the urban heat island effect[6] is evident, a gradual increase in electricity consumption can be observed in connection with the increased use of air conditioners.

While in 2020 approximately 7 percent of Czech households were equipped with them[7], by last year this figure had risen to more than 16 percent[8]. With regard to climate development and the increasing number of tropical days, a further increase in this share can be expected[9], resulting in a higher load on the grid during summer heat waves.

If the share of air-conditioned households were to reach the level of the USA (90 percent of households) in the future, for example, the peak load on the system would increase by an estimated 2-4 GW, which is equivalent to the output of 2 to 4 large nuclear units.

However, this situation would only occur if all newly connected air conditioners were powered by the grid and not by local sources such as photovoltaic power plants. These can significantly contribute to reducing the grid load as the number of air-conditioned households increases.

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[5] Energy regulatory office: Annual report on the operation of the Czech electricity system for 2024, https://eru.gov.cz/rocni-zprava-o-provozu-elektrizacni-soustavy-cr-pro-rok-2024

[6] European Commission, Joint Research Centre: Urban heat islands: managing extreme heat to keep cities cool, https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/urban-heat-islands-managing-extreme-heat-keep-cities-cool-2024-07-22_en

[7] Programujeme.cz: Aktuální průzkum Energie ČS na téma technologií,, http://programujte.com/clanek/2020030501-aktualni-pruzkum-energie-cs-na-tema-technologii/

[8] PRO-ENERGY magazín: Chlazení levnější než vytápění. Na kolik vyjde provoz klimatizace, https://www.pro-energy.cz/news/detail/1158269

[9] Envirometr: Jak se mění teploty v Česku?, https://www.envirometr.cz/souvislosti/jak-se-meni-teploty-v-cesku

Figure 3: Rooftop and facade photovoltaic power plants can significantly contribute to reducing the load on the grid during the summer heat. The picture shows a residential complex in Brno, cooled by heat pumps with deep wells and equipped with a rooftop and facade photovoltaic power plant with an output of 295 kWp



Source: Sunlux

Currently, only about a third of Czech households equipped with air conditioners use photovoltaics. In the future, it is therefore desirable for air conditioners to be installed together with photovoltaics, both in the case of residential buildings (whether family houses or apartment blocks), and in administrative or industrial buildings.

Another option for reducing the load on the grid during heat waves is consumption-side measures. These include, for example, pre-cooling of buildings using their thermal inertia; dynamic tariffs, which allow shifting part of household consumption outside peak loads; aggregation of flexibility, which includes, in addition to cooling, for example, controlled charging of electric vehicles or some industrial processes (pumping, industrial heat production, compressed air storage, etc.).

These methods are currently only used to a limited extent in the Czech Republic. The exception is part of industrial flexibility, which is already involved in the provision of support services. On the other hand, pre-cooling of buildings, air conditioning control, dynamic tariffs and aggregation of flexibility in the household sector are mainly in the pilot project or early development phase.

Impact on electricity production and distribution

On the electricity generation side, high temperatures during heat waves cause problems with cooling thermal and nuclear power plants. Not only do they generally reduce cooling efficiency, but in the case of flow-through cooling using watercourses, high temperatures can limit the operation of the power plant due to the environmental limits set for the temperature of the

discharged water. In the past, production had to be limited for these reasons, for example, at the Mělník coal power plant.

This method of cooling is used by only a few facilities - in addition to the aforementioned Mělník power plant, it was also used in the Hodonín coal and biomass power plant, which has, however, transitioned to closed-circuit cooling with a cooling tower since 2024.[10] Therefore, it cannot be generally assumed that high temperatures alone would cause serious problems with electricity production (drought is another matter, see below).

Figure 4: closed-circuit fan cooling tower of the Hodonín power plant



Source: ČEZ

From the point of view of the operation of the distribution and transmission system, heat waves pose a problem primarily for overhead power lines. Their conductors lengthen due to thermal expansion, which leads to increased sag and thus a reduction in clearance from surrounding vegetation. As a result, the risk of failures caused by contact of conductors with tree branches or by electrical arcing increases. For this reason, regular maintenance of vegetation in the protective zones of the lines is necessary, especially during the growing season.

At high ambient temperatures, the current carrying capacity of overhead lines also decreases. Operators must therefore limit the maximum transmitted power so as to prevent excessive heating of the conductors and their increased sag.

[10] ČEZ: Unikátní izraelský chladicí systém v Hodoníně ročně ušetří 57 milionů kubíků vody, sníží spotřebu o 97 %, https://www.cez.cz/cezes/cs/o-spolecnosti/aktuality/unikatni-izraelsky-chladici-system-v-hodonine-rocne-usetri-57-milionu-kubiku-vody-snizi-spotrebu-o-189727

These limitations must be taken into account when managing the distribution and transmission systems. One possible solution to this problem is the use of underground cable lines, which also addresses problems with wind gusts or icing (see below).

In addition to overhead power lines, prolonged heat can also affect the performance of electrical transformers. High temperatures accelerate the aging of their insulation system, which increases the likelihood of failure.

In addition to ensuring better cooling of transformers, online transformer monitoring is an effective tool that tracks important operating parameters and helps prevent potential problems. This measure is already standard for key transformers at the transmission system level and is gradually being introduced at lower voltage levels.

Drought

Prolonged drought episodes impact the availability of cooling water for thermal and nuclear power plants, negatively affect the operation of hydroelectric power plants and can also reduce fuel production for biomass power plants.

According to the Czech National Adaptation Strategy, currently about 85% of gross electricity generation comes from sources that may be significantly affected by long-term drought. In 2040, the share of these sources (including combined cycle power plants or heating plants) in gross electricity generation is expected to remain roughly the same, i.e. about 85%.[11]

At the same time, the energy sector is one of the largest consumers of water in the Czech Republic. Czech power plants account for approximately one third of the total consumption of surface and groundwater. However, most of this water is returned to the watercourses after use.[12]

In the future, it is important to continue reducing cooling water consumption, including by switching to a closed cooling cycle. For example, the newly built units of the Dukovany nuclear power plant are to use hybrid cooling to minimize water consumption so that production does not have to be limited due to drought.[13]

In this respect, sources that do not require cooling for their operation, such as photovoltaic or wind power plants, have an advantage. However, their share is still very small - in 2024 it was just under 6 percent of gross electricity production.[14]

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[11] Ministry of the Environment: Climate change adaptation strategy in the Czech Republic, https://mzp.gov.cz/system/files/2025-03/OAZK_Narodni_adaptacni_strategie-aktualizace_20211026.pdf

[12] Czech Statistical Office, Statistika a my: Vodní hospodářství v Česku, https://statistikaamy.csu.gov.cz/vodni-hospodarstvi-v-cesku

[13] Hospodářské noviny, V Dukovanech vyroste dvojice obřích věží. Neobvyklá technologie má zajistit, že jaderné bloky si vystačí s vodou, https://archiv.hn.cz/c1-67841200-v-dukovanech-vyroste-dvojice-obrich-vezi-neobvykla-technologie-ma-zajistit-ze-jaderne-bloky-si-vystaci-s-vodou

[14] Energy regulatory office: Annual report on the operation of the Czech electricity system for 2024, https://eru.gov.cz/rocni-zprava-o-provozu-elektrizacni-soustavy-cr-pro-rok-2024

Storms and wind gusts

The most common cause of power system failures during storms and high winds is trees and branches falling onto overhead power lines. Strong winds can not only break branches, but also topple entire trees, which can fall into the protective zone of the power line. This can subsequently cause an interphase short circuit, a short circuit to ground, a broken wire or damage to the mast.

Strong lateral gusts can then, under certain circumstances, deflect the conductors sufficiently to cause electrical arcing. In extremely strong winds, such as those that accompanied hurricanes Kyrill (2007) or Herwart (2017) in the past, the structure of power line masts can be deformed, the anchors damaged, or they can even collapse.

Figure 5: damaged overhead power lines in the municipality of Moravská Nová Ves after a tornado in 2021



Source: Tadeáš Bednarz, Wikimedia

An effective way to address problems with high winds, as well as conductor sag during heat waves, is the use of underground cable lines.

In the case of the distribution system, the share of underground cable lines at the low voltage level is estimated to be between 70 and 80 percent. It is especially common in cities and newer developments. In the case of high voltage, the share of underground cable lines is significantly lower, only around 40 to 50 percent, but it is gradually increasing.

In the case of the transmission system, most of the wires are routed above ground. The only exception is a part of the 110 kV lines in large cities or industrial areas. The lines at voltage levels of 220 and 400 kV are almost entirely overhead.

The reason is mainly costs - while in the distribution system underground lines are approximately 2 to 5 times more expensive than overhead lines, in the case of transmission networks this difference can be as much as twentyfold. The disadvantage of underground cable lines is also the more complex localization of faults and the more expensive replacement of damaged sections, although faults occur far less frequently in underground cables than in overhead lines.

For overhead lines, their resilience is increased primarily by proper design, construction and subsequent maintenance with regard to the possible occurrence of the described phenomena. This includes, for example, increased spacing between conductors, the use of dampers and interphase spacers, sufficiently wide and properly maintained protection zones, etc.

Floods

Floods can lead to sudden flooding of substations and transformer stations. Water entering transformers, switchboards, but also, for example, cable penetrations, cable chambers or cable routes can damage insulation, cause short circuits, and put the affected equipment out of operation.

Increased water levels can also threaten the operation of hydroelectric and thermal power plants. Water can enter engine rooms, clog intake with sediment, damage cooling water pumping stations, undermine the foundations of electrical pylons, etc.

Flooded areas, including land communications, subsequently complicate the access for repair teams and therefore the restoration of damaged equipment.

Figure 6: example of inappropriately located charging infrastructure located in a flood zone



Source: Megan Harwood-Baynes, X

Basic measures for preventing the consequences of floods include the construction of substations above the level of a hundred-year or thousand-year flood level, the use of waterproof cable penetrations, the protection of critical elements using mobile barriers, etc.

An integral part is preparedness for similar events in the form of developed crisis plans, preventive shutdowns in the event of a risk of flooding, ensuring backup power supply, etc.

In Czech conditions, floods primarily threaten local distribution systems, whose elements are located in flood areas. Flooding of these elements is often the cause of outages during floods.

Icing

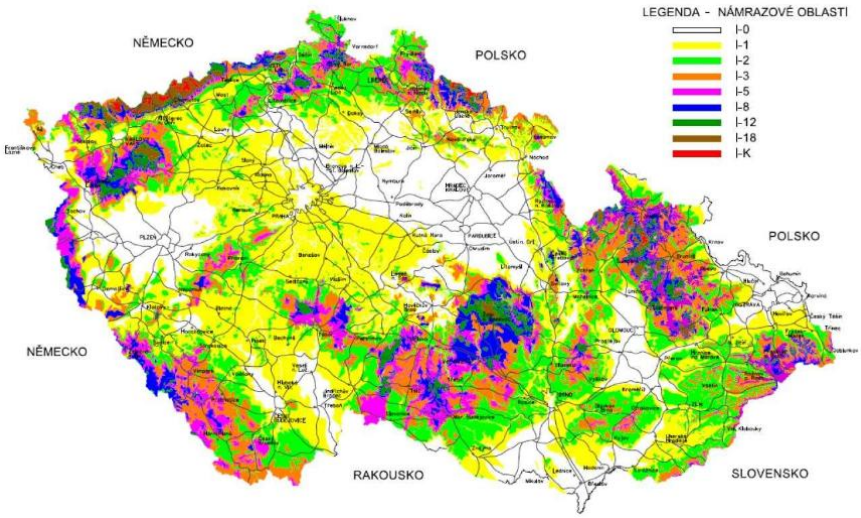
Icing, caused by a combination of temperatures around zero, wind, fog and freezing rain, poses a danger to electrical conductors and power line poles.

A thick layer of ice can increase the weight of outdoor conductors several times, which increases their sag and the mechanical stress on the poles. In extreme conditions, the conductor can even break or the pole can collapse.

A specific phenomenon is the so-called galloping, which is associated with strong winds acting on an asymmetric layer of ice on the conductors, causing them to oscillate with an amplitude of several meters. This can lead to contact between phases, possibly damage to insulators or breakage of conductors. This phenomenon is particularly hazardous for extra-high voltage overhead lines.

As with strong winds, icing can also cause indirect damage due to falling branches or uprooted trees loaded with a thick layer of ice.

Figure 7: map of icing areas in the Czech Republic



Source: EGÚ Brno

Icing risk is documented in icing zone maps, which quantify exposure and serve as a basis for designing new lines.

In connection with climate change and changing conditions, a possible increase in episodes of wet snow and freezing rain can be expected in areas where the risk of icing has been relatively low so far.

Similar to wind gusts or increased deflection due to high temperatures, the use of underground cable lines is an effective solution. At the same time, it is necessary to take into account the increased costs that this solution brings.

Summary: Is the Czech energy infrastructure ready for climate change?

The impacts of climate change on the energy infrastructure in the Czech Republic are already being felt and can be expected to intensify in the coming decades. The Czech energy sector is vulnerable to a number of climate risks described in the previous text. These phenomena can affect both electricity production and the operation of the transmission and distribution system, with any major outages having a significant impact on the functioning of the entire society.

In terms of preparedness, it can be stated that the Czech energy sector has a number of adaptation measures that are gradually increasing its resilience. Transmission and distribution system operators have been investing in the modernization of networks, automation of fault management, monitoring of key equipment, gradual undergrounding of distribution lines and increasing the resilience of substations and transformer stations.

An important element of resilience is also the relatively high level of interconnection of the Czech electricity system with neighboring countries and a robust crisis management system[15], which is regularly tested in emergencies. The readiness of resources providing support services for island operation and so-called dark start is regularly checked by the Energy Regulatory Office.[16]

The issue of energy adaptation to climate change is also enshrined in a number of strategic and legislative documents. The National Climate Change Adaptation Strategy[17] and the subsequent National Climate Change Adaptation Action Plan [18] identify energy as one of the key vulnerable sectors and propose measures aimed at strengthening the resilience of infrastructure, reducing dependence on water resources and improving preparedness for extreme weather events. The issue of climate resilience is also addressed in the State Energy

[15] Hasičský záchranný sbor ČR: Systém krizového řízení, https://hzscr.gov.cz/clanek/krizove-rizeni-a-cnp-system-krizoveho-rizeni-system-krizoveho-rizeni.aspx
[16] Energy regulatory office: Kodex PS, část II, https://eru.gov.cz/kodex-ps-cast-ii-sdeleni
[17] Ministry of the Environment: National Climate Change Adaptation Strategy, https://mzp.gov.cz/system/files/2025-03/OAZK_Narodni_adaptacni_strategie-aktualizace_20211026.pdf
[18] Ministry of the Environment: National Climate Change Adaptation Action Plan, https://mzp.gov.cz/system/files/2025-03/OAZK_NAP_adaptace-aktualizace_20211025_0.pdf

Concept[19], the Climate protection policy[20], the State environmental policy[21] and most recently the National Climate and Energy Plan [22].

Another impetus for increasing the resilience of critical infrastructure is the requirements of European legislation. The Directive of the European Parliament and of the Council on the Resilience of Critical Entities (CER) obliges Member States to systematically assess risks, including risks related to climate change, and to take appropriate measures to increase the resilience of critical infrastructure. The Czech Republic is currently preparing to implement these requirements into national legislation.

Despite the above-mentioned progress, there are areas in which the preparedness of the Czech energy infrastructure is not yet sufficient. Electricity generation remains highly dependent on sources requiring large amounts of water for cooling, a significant part of the transmission system remains exposed to risks associated with extreme weather, and adaptation measures in the areas of demand flexibility, demand management, and energy decentralization are only in the initial stages of development. Another problem is that climate risks have historically been assigned low priority in energy infrastructure planning and are therefore not yet consistently integrated into investment decisions in all cases.

Overall, it can be stated that the Czech energy infrastructure is relatively well prepared for the current manifestations of climate change and its resilience has been increasing in recent years. At the same time, however, the expected intensification of climate extremes will require further investment.

In addition to traditional measures such as strengthening the physical resilience of networks, decentralized energy sources, battery storage, flexibility aggregation and smart demand management can also make a significant contribution to increasing climate resilience. These technologies can help limit the impacts of local disruptions in the future and accelerate the restoration of energy supplies after emergencies.

[19] Ministry of Industry and Trade: State Energy Concept, https://mpo.gov.cz/cz/energetika/statni-energeticka-politika/statni-energeticka-koncepce--223620
[20] Ministry of the Environment: Climate protection policy, https://mzp.gov.cz/cz/ministerstvo/politika-a-strategie-mzp/pripravovane-strategicke-dokumenty/politika-ochrany-klimatu
[21] Ministry of the Environment: State environmental policy, https://mzp.gov.cz/cz/ministerstvo/politika-a-strategie-mzp/statni-politika-zivotniho-prostredi
[22] Ministry of Industry and Trade: National Energy and Climate Plan of the Czech Republic, https://mpo.gov.cz/cz/energetika/strategicke-a-koncepcni-dokumenty/vnitrostatni-plan-ceske-republiky-v-oblasti-energetiky-a-klimatu--285293/