Baking Baku

The economic impact of climate change on Eastern Europe

November 2024

Above: Oil drilling in Baku, Azerbaijan. Credit: Gulustan

christian aid

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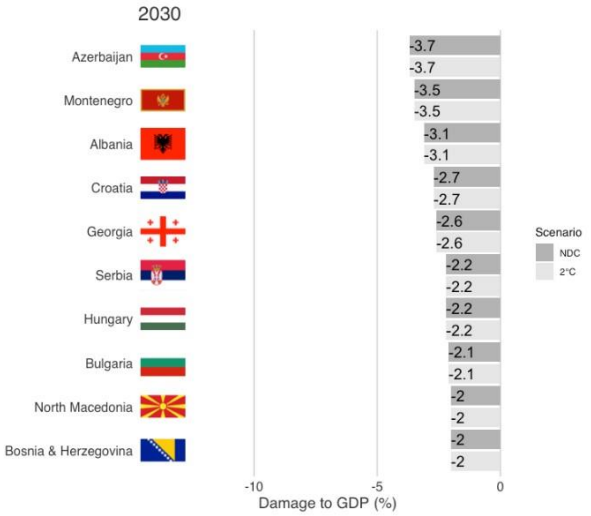
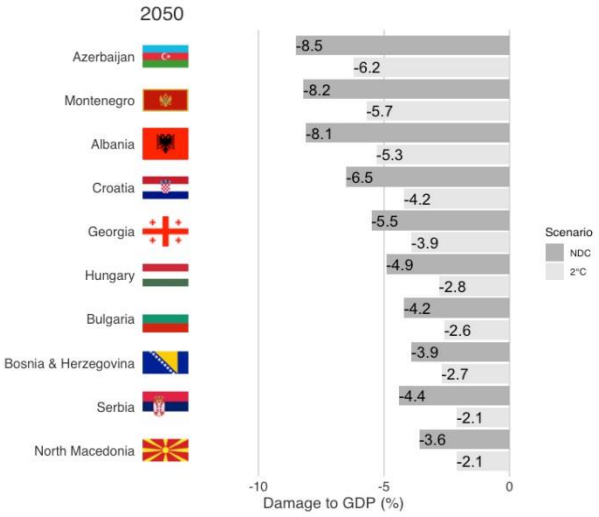
Contents

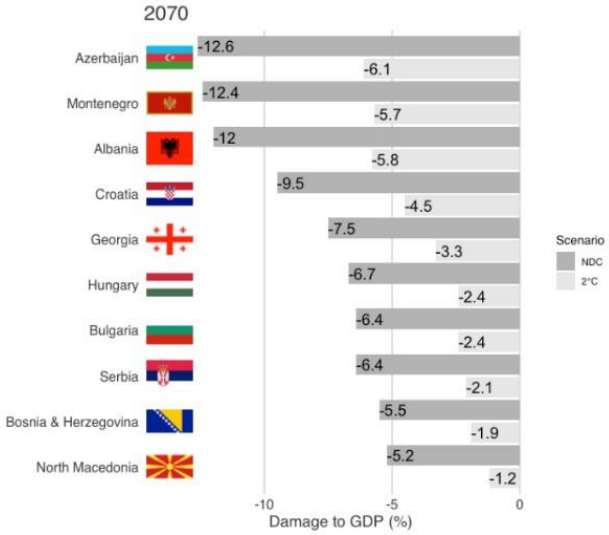
Executive Summary



As host of COP29, Azerbaijan will be at the centre of this year's crucial climate summit with the fate of the world's most vulnerable people at stake. This report shows that the host nation also happens to be the most vulnerable country in the region to climate change induced economic harm. The analysis based on the latest scientific models shows that Azerbaijan's income is expected to suffer a hit of around 12.6% in 2070 if the world continues to follow a trajectory where current climate pledges (NDCs) are enacted. This would result in global heating of approximately 2.8C by the end of the century. In this scenario the hit to GDP in 2050 would be around 8.5%. If global average temperature rise is kept to 2C the economic harm will be reduced but still significant, with more than a 6% hit to the country's GDP in 2050 and 2070.



As host, COP29 President Mukhtar Babayev has a responsibility to the rest of the world to push for a strong outcome that will help deliver climate finance, reduce emissions and accelerate the 'just transition' away from fossil fuels. As one of Europe's biggest oil producers, Azerbaijan is a major cause of the climate crisis. Analysis from Climate Action Tracker last month described Azerbaijan's climate policy as "critically insufficient" citing the fact the country had actually weakened already inadequate climate targets.[1] The more fossil fuel Azerbaijan produces the greater the suffering will be on its own citizens and those of its neighbours in the region.

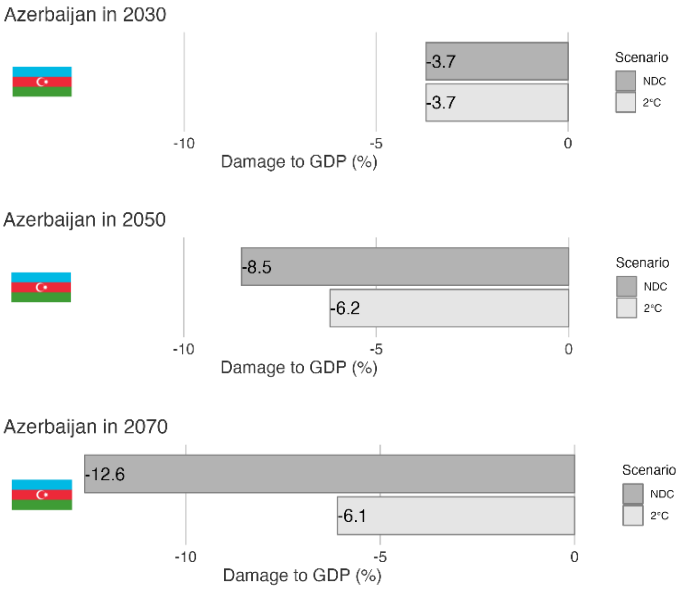


As this report shows, Eastern Europe already faces a changing climate which will have a significant impact on national economies, exacerbating problems around agriculture, tourism, human health and conflict. The European Commission warns that temperature extremes are projected to be a key impact in central and eastern Europe. Combined with reduced summer precipitation, this can increase the risk of droughts, and is projected to increase energy demand. The intensity and frequency of river floods in winter and spring is projected to increase due to greater winter precipitation. Climate change is also projected to lead to higher crop yield variability and more frequent forest fires.[2]

The economic threat to Eastern Europe:

The top 10 most impacted nations

Azerbaijan



Climate impacts

This report shows that Azerbaijan faces the most severe economic impacts from climate change of all countries in the Eastern European region. It will suffer a hit to its GDP of around 8.5% by 2050 and 12.6% by 2070 if the world follows a trajectory in line with current NDC commitments, estimated to result in global temperature rise of 2.8C by the end of the century. In a scenario where the world limits this heating to 2C the economic hit in 2050 and 2070 will still be more than 6%. It is clear that Azerbaijan would benefit from seeing global heating kept below these levels and would suffer less economic damage if climate change can be kept to the 1.5C target set out in the Paris Agreement.

A World Bank report from 2023 outlined how Azerbaijan's agriculture will soon be constrained by more frequent and severe adverse climate impacts.[3] Agriculture is a sector critical to the country's nonhydrocarbon economy and accounts for 36% of total employment. As almost half of the population lives in rural areas, the sector is crucial to vulnerable households' livelihoods. The effects of temperature and precipitation changes on Azerbaijan's agriculture are already visible, and absent adaptation actions, they will thwart its future potential. Rain-fed crop yields are projected to decline between 14% and 20% by 2060 on average, with high-value crops showing higher declines. Irrigated crops are also at risk from projected water shortages with estimated losses of over 60% for some crops in southern regions and over 20% in the Eastern Lower Kura basin. Livestock is expected to be subject to similar trends, including through the direct effects on livestock health. Imminent water security risks compound existing sector challenges. Azerbaijan already faces a permanent overall water resource deficit today. While future projections are characterized by seasonal variability, water scarcity is projected to increase further across all major cropland areas. Coupled with climate change-induced variability, this will compound Azerbaijan's dependency on transboundary water sources.

Azerbaijan's population is vulnerable to drought and flooding. Droughts are already a frequent occurrence, and can lead to forest fires such as those experienced in 2014, when 59 hectares of forest were damaged by 12 fires.[4] Flooding is a regular issue in the country, stripping the land and damaging soil. The Azerbaijan Ministry of Ecology and Natural Resources estimates it causes the Azerbaijan economy $18-25 million of damages each year.[5]

The World Bank warns that a hotter climate would pose multiple threats to public health in Azerbaijan, increasing the rate of heat related medical issues in urban areas such as Baku, and lengthening the seasonal window during which malaria occurs. There is a risk that the impacts of climate change will be disproportionately felt by those least able to adapt. For example, poorer communities in rural areas are more reliant on rain-fed agriculture, which is likely to be negatively impacted by more frequent droughts. Poorer communities are often dependent on poor quality water infrastructure, lack diversified income sources and assets, and will be least able to adapt their livelihoods to disaster risks such as drought and extreme heat.[6]

Azerbaijan's Caspian Sea, the world's largest lake, is also coming under pressure from climate change. A 2020 study called for greater attention to falling water levels in inland seas and reservoirs, like the Caspian. The study warned that water levels in the Caspian Sea could fall by 9-18 metres by the end of the century.[7] It paints a bleak picture of the impact of such declines on the ecosystem and people. "As the livelihoods and food security of millions of people depend on the Caspian Sea, a loss of these ecosystem services will have drastic socioeconomic consequences and may trigger local and regional conflicts—in an ethnically diverse region that is already rife with tensions," the authors write.

Azerbaijan's cotton industry, a key plank of the economy in the 1980s, is expected to be one of the crops experiencing the greatest yield decline due to climate change and rapid soil degradation, according to experts in the country trying to develop climate resistant varieties.[8]

Climate policies

Azerbaijan, despite being host of COP29, is one of a tiny group of countries that has actually weakened its climate target in contradiction of the requirement of the Paris Agreement's Article 4.3 that each Nationally Determined Contribution (NDC) submission will be more ambitious than its previous one.

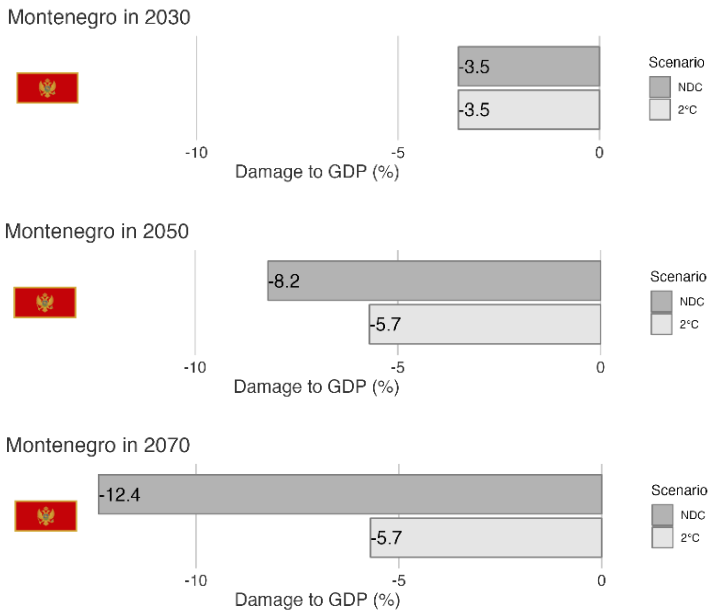
Climate Action Tracker(CAT) conducted a full country analysis of Azerbaijan's climate policies in September 2024 and gave them a rating of "critically insufficient". It said that Azerbaijan's target and current policies are far from consistent with the Paris Agreement's 1.5C temperature limit. Total GHG emissions are projected to continue rising by around 20% to 2030, in stark contrast to the emissions reductions necessary to meet its climate commitments. Energy-related methane emissions are increasing quickly, whereas for 1.5C alignment they would need to drop by about 66% below 2020 levels by 2030.[9]

Azerbaijan appears to have abandoned its 2030 emissions target, moving backward instead of forward on climate action. Its renewable energy targets remain weak. Azerbaijan's economy is dependent on fossil fuel production and the government plans to increase fossil gas extraction by more than 30% over the coming decade. Although it recently unveiled its first large scale solar park, Azerbaijan plans to export the gas that will be saved by this new solar supply. Emissions from exported fossil fuels are twice as high as domestic emissions.[10]

Azerbaijan's state-owned oil and gas company, Socar, and its partners are set to raise the country's annual gas production from 37 billion cubic metres today to 49 billion cubic metres by 2033. Socar also recently agreed to increase gas exports to the European Union by 17% by 2026.[11]

CAT said that along with setting a more stringent climate target, Azerbaijan needs to significantly increase the ambition of its climate policies to reverse the present rapid growth in emissions and set its emissions on a firm downward trajectory.

Montenegro



Climate impacts

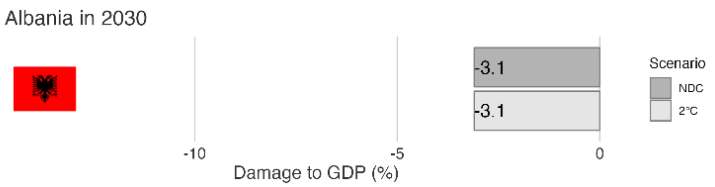
The average annual temperature in 2023 was 2.5C higher than the climatological norm for the period between 1961 and 1990. 2023 was the hottest year on record over much of the country.[12] Climate change in Montenegro is likely to result in more droughts as well as heavy rains affecting agriculture, forestry and water resources.[13]

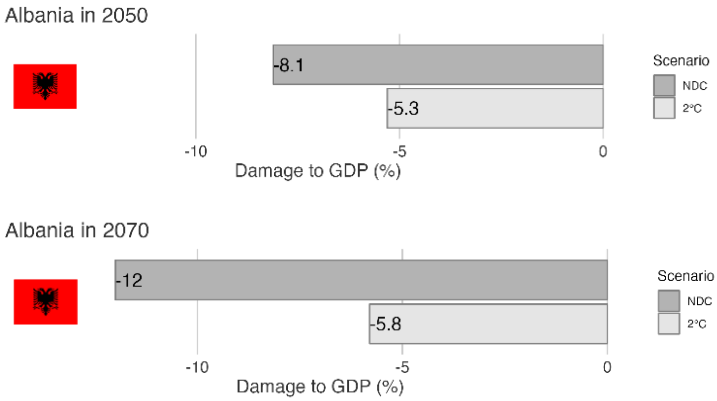
The country's Mediterranean conditions allowed Montenegro to develop a rich heritage of grape and wine production, which is becoming threatened by climate change. Most of the vineyards are located in the vicinity of the capital, Podgorica, where the temperature is projected to increase. A 2024 study found that regardless of the shared socioeconomic pathway scenario (SSP), the temperature increase threatens Montenegrin wine production, as the baseline conditions will be surpassed. Temperature increase will be major during the hottest quarter, which will be around 4C. Regarding the growing season, the average temperature from April to October, will reach 24C, which is above traditional thresholds for successful grape growing.[14]

Climate policies

Montenegro submitted its enhanced NDC in June 2021. The NDC envisages GHG emission decrease of 35% by 2030, in comparison to the base 1990.[15] The country aims to have 50% share of energy from renewable sources in its gross energy consumption by 2030. In October 2024 it announced the launch of the Montenegro Energy Growth and Acceleration (MEGA) national study. The initiative aims to identify sites with significant energy potential that also pose minimal ecological and social conflicts for developing solar and wind power plants.[16] Montenegro's emissions primarily come from its energy intensive coal and aluminium industries, while the residential and transport sectors account for the largest share of final energy consumption in the country.[17]

Albania





Climate impacts

Albania has been struck by numerous, costly extreme events, with increasing frequency in its recent history due to climate change. Over the last two decades, the frequency of extremes has grown, with floods and forest fires becoming more frequent as the impact of climate change is being increasingly felt. The International Monetary Fund states that between 1980 and 2021, extreme events are estimated to have affected about 438 thousand people, a fifth of the Albanian population, and caused damages amounting to $802 million. On average, Albania is hit by close to one disaster per year, with each extreme weather event causing damage of about 1.3 percent of GDP and affecting about 5000 per 100,000 inhabitants.[18]

The increasing risk of river floods and droughts is associated with higher risk of pressure on water supply infrastructure and given the high reliance of the country on hydropower, putting at risk electricity generation. Increased temperatures and precipitation variability are expected to have a negative impact on the agricultural sector, which represents about 20% of the economy. Extreme temperatures pose a threat to agricultural production and heavy rainfall events increase the risk of crop losses. In the decade ending in

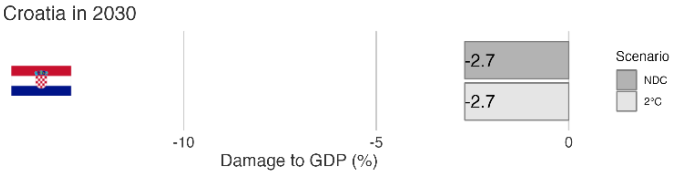
2020, forest fires have burnt over 200,000 hectares, equal to 19% of the total remaining forests.[19] **Climate policies**

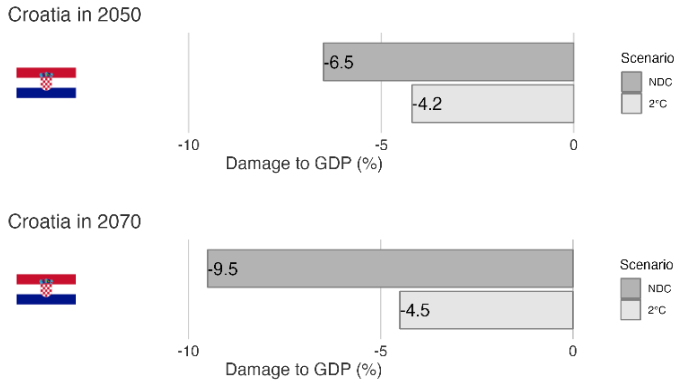
Albania is largely dependent on hydropower for its electricity supply. This gives it an advantage in decarbonising its electricity sector but also makes it highly vulnerable to the changing climate. Massively fluctuating hydropower generation means that despite the addition of hundreds of megawatts in new plants in recent years, the country has to import electricity most years.[20]

Until 2017 Albania only offered renewable energy incentives for hydropower and as a result solar and wind have remained underdeveloped. However, in late 2023, a 140 MW solar plant came online.[21] At the same time, uncontrolled hydropower development has caused increasing discontent and damage to protected areas.[22]

Albania submitted a revised national climate plan (NDC) under the Paris Agreement in 2021. It committed to an unconditional emissions reduction target of 20.9% by 2030 compared to business as usual. This is an increase compared to the first NDC which aimed to reduce emissions by 11.5% by 2030 compared to 2016 levels.[23]

Croatia





Climate impacts

Croatia's key climate-related risks primarily affect the agricultural, water, and energy sectors through seasonal flooding, decreased precipitation, and periods of drought.[24]

Temperatures are already rising, while precipitation is decreasing and more extreme weather events are occurring, especially droughts and heat waves. Croatia is also at risk of forest fires, flooding, water scarcity and extreme heat. This is expected to result in impacts to agriculture and water sectors as well as to wider population health. Vulnerable groups, such as those with fewer economic opportunities and the elderly are particularly at risk of extreme weather events and increasing impacts of climate change.

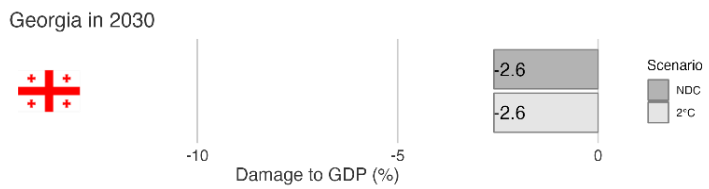
The rising temperatures and lack of water could also have an economic impact on the Croatian tourist industry which contributed around 20% of GDP in 2021. Jehan Arulpragasam, World Bank Country Manager for Croatia, said: *"Croatia is increasingly exposed to worrying climate change trends which could lead to droughts and low supply of water in the summer months. This would affect not only Croatia's tourism economy, but also the health and well-being of its citizens."*[25]

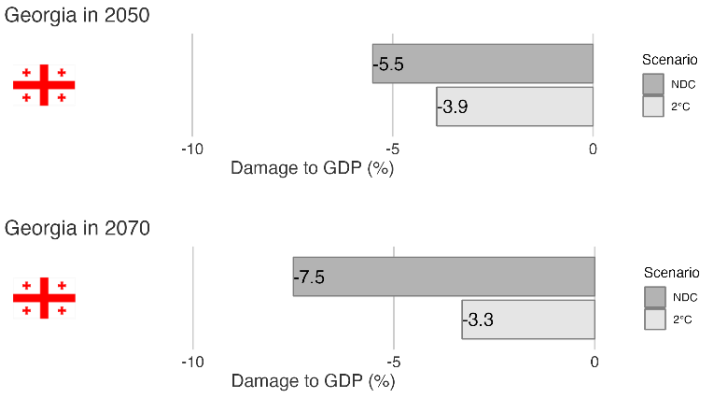
Climate policies

Croatia ranks 35th out of 67 in this year's Climate Change Performance Index, making it an overall lowperforming country. The Index assesses a selected group of nations based on their climate policies and deployment of clean and dirty energy. Croatia's climate performance is characterised by high greenhouse gas emissions, above the EU average and high energy consumption. The index is particularly critical of the fossil fuel subsidies still in place in Croatia and fossil fuel infrastructure is being further developed.[26]

However progress is being made in renewable energy installation. Croatia has a high level of energy imports including oil, gas and electricity, due in part to the lack of competitiveness of old national facilities. Lowering electricity imports by building more solar and boosting the energy independence of island communities is seen as essential. Croatia is a signatory to the Declaration on Clean Energy for EU Islands.[27]

Georgia





Climate impacts

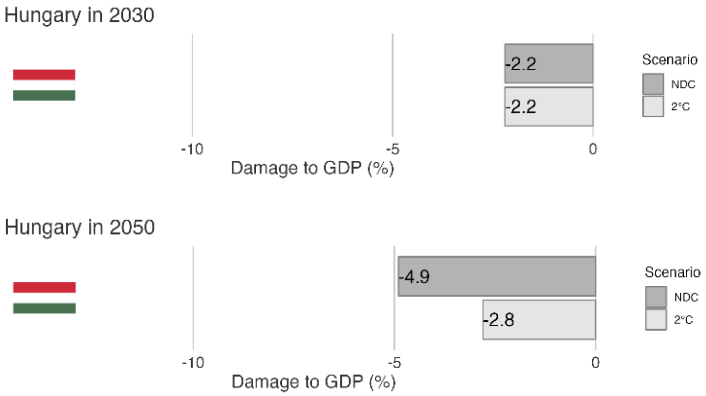
Average temperatures in Georgia have increased steadily since the 1960s and are projected to rise by more than the global average by the end of the 21st century. The frequency of heat waves is also projected to increase significantly by the end of the century under higher emissions pathways, representing major risks to human health, livelihoods, and biodiversity. Rapid retreat of glaciers is expected and is likely to shift the regional hydrological regime, increasing the risk of flooding and ultimately driving transitions in local ecosystems. The effects of rising temperatures on agricultural output could threaten an important source of income and employment in poorer rural areas and may consequently increase inequality and raise the risk of malnourishment. The capital city, Tbilisi, is subject to the urban heat island effect, making its residents vulnerable to health risks as the frequency of extremely high temperatures increases over the coming decades.[28]

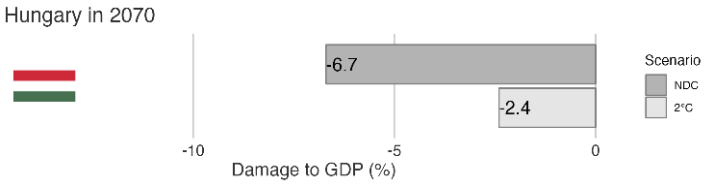
Climate policies

Georgia submitted its revised NDC in 2021. It took on a conditional commitment to reduce greenhouse gas emissions by 50-57% by 2030 compared to 1990 levels, subject to international support. The country also increased its unconditional greenhouse gas emissions reduction target to 35% by 2030 compared to 1990 levels.[29]

Georgia has significant renewable energy potential, particularly in hydro, wind and solar energy. The country also benefits from high solar radiation, with around 250-280 sunny days per year. Renewable energy sources hold immense potential for electricity generation, with opportunities for foreign investment.[30] Georgia's Integrated National Energy and Climate Plan (NECP) outlines aims to increase the share of renewable energy in total final energy consumption by 27.4% by 2030.[31]

Hungary





Climate impacts

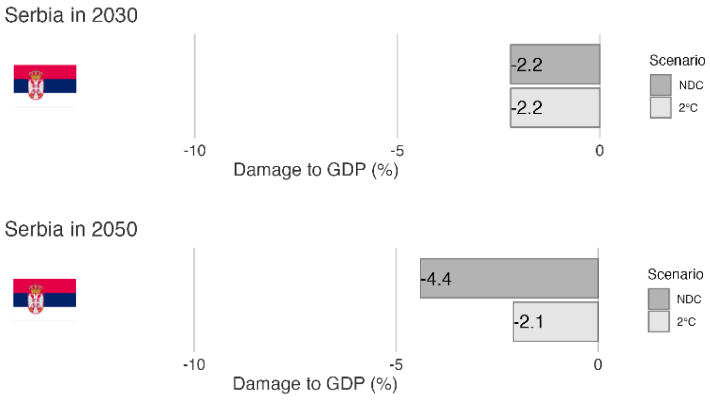
Hungary's annual average temperature increased by 1.15C between 1907 and 2017, outpacing the global temperature rise (+0.9C) over the same period, with spring and summer heating up more quickly than autumn and winter. In particular the heating rate has accelerated significantly in the last four decades, affecting the Mecsek, the central Danube region and the eastern part of the country the most. Since 2000, the average rate of heating has been higher (0.06C per year) than the global average (0.03C).[32]

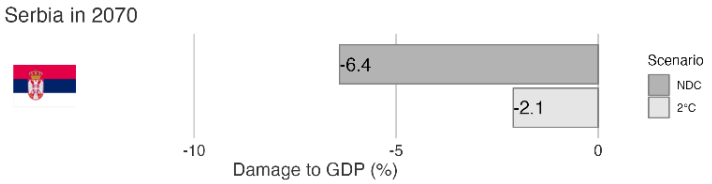
Agriculture is Hungary's most vulnerable sector to climate change with rising temperatures, precipitation changes, floods and drought the most likely impacts from climate change in the coming years.[33] Drought and water management pose particular dangers which are forecast to contribute to soil degradation and worsening food security.[34]

Climate policies

Hungary ranks 49th out of 67 countries of the Climate Change Performance Index which assesses a selected group of nations based on their climate policies and deployment of clean and dirty energy.[35] It criticises the Orbán government for regularly trying to undermine EU climate legislation as well the self-harming approach to renewables. Current legislation doesn't allow wind turbine installation and a restriction on grid access for solar energy also hinders expansion of this form of renewable energy. On a positive note, an air ticket tax was introduced, albeit, only a modest one, and reconstruction of some major railway lines and replacement of old rolling stock has continued.

Serbia





Climate impacts

Serbia is heating more intensively and faster than the global average. While the observed increase in the global average temperature is 1.1C, Serbia is already at 1.8C, and in the summer, it is as much as 2.6C. At the same time, since 2000, Serbia has faced several significant extreme climate events that have caused significant material and financial losses, as well as the loss of human lives. The total damages caused by extreme climatic events between 2000-2020 amount to 6.8 billion euros. More than 70% of the damages were caused by droughts and high temperatures due to climate change and extreme weather events.[36]

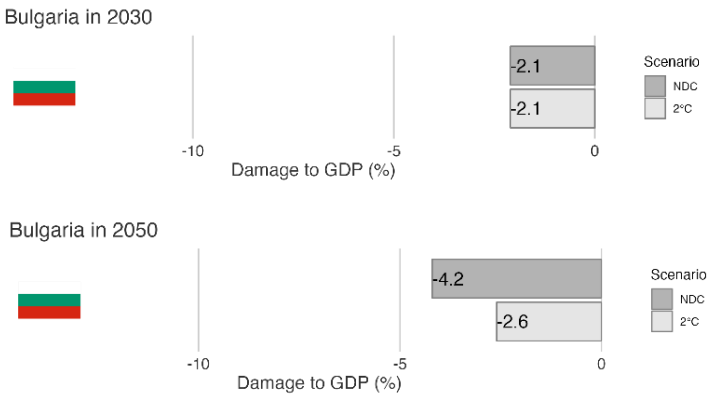
Climate change is causing a rise in average temperatures and longer periods of drought. These changes significantly affect agriculture, water supply, and human health. Droughts lead to reduced crop yields, water shortages, increased risk of wildfires, and land degradation.[37]

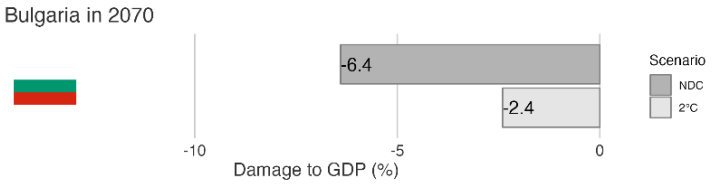
Climate policies

Energy in Serbia is dominated by fossil fuels, despite the public preference for renewable energy, especially solar and wind.[38] Serbia's energy mix in 2021 comprised coal (45%), oil (24%), gas (15%), and renewables (16%). Bioenergy and hydroelectric power were the leading contributors within the renewable energy category, accounting for 67% and 29% of the renewable supply, respectively.[39]

Serbia submitted its revised NDC in August 2022. Serbia committed to an unconditional emissions reduction target of 13.2% compared to 2010 levels, or 33.3% compared to 1990 levels, by 2030. This is an increase compared to the first NDC which aimed to reduce greenhouse gas emissions by 9.8% by 2030, compared to 1990 levels. The new target is economy-wide and includes key economic sectors such as energy production and consumption, agriculture, transport, industry, waste management, and forestry.[40]

Bulgaria





Climate impacts

Bulgaria has suffered from numerous extreme weather events in recent years, with injuries, deaths and material losses, such as flash floods in January 2021, as well as droughts, tornadoes and storms. The number of extreme weather events rose by 30% in Bulgaria in the period 1991–2007, compared with the period 1961–1990. According to the Government's Ministry of Health by 2050, the number of extreme weather events in Bulgaria could triple.[41]

Around half of Bulgaria's land is used for agricultural purposes, which contributes around 5% to the country's GDP. Agricultural production has already been affected by climate change in Bulgaria, with extreme weather events, including droughts and floods, and overall rising temperatures posing significant challenges. Land degradation is one of the most pressing environmental concerns in Bulgaria and is mostly manifested through water, wind and irrigation erosion, and through soil acidification and salinisation. At least 50-60% of the country's land base is affected by some form of land degradation.[42]

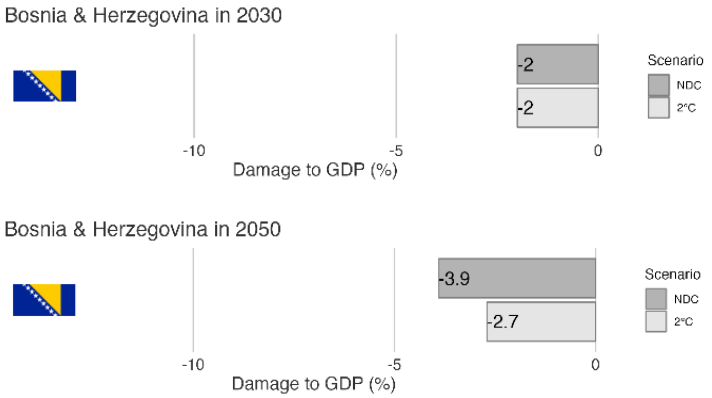
Climate policies

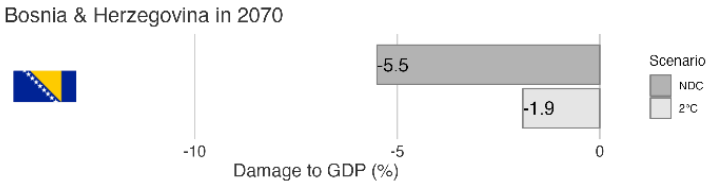
Bulgaria ranks 46th in this year's Climate Change Performance Index, down 10 spots from the previous year and among the low-performing countries. Its coal plans are some of the most polluting in the EU.[43]

In 2005, Bulgaria's total greenhouse gas emissions decreased by 37% compared with 1990, while in 2019 they were 44% below the 1990 level. Reasons for this decline are due to structural changes in industry, an increased share of hydro and nuclear electricity and implementation of energy efficiency measures in the housing sector.[44]

However Bulgaria lacks 2030 and 2050 carbon emissions targets and its coal power phase-out is planned for 2038, which is not in line with other EU countries' aims to phase-out coal by 2030. In a survey by the European Investment Bank, three quarters of Bulgarian respondents (75% vs the EU average of 78%) think that climate change is a very serious problem.[45]

Bosnia and Herzegovina





Climate impacts

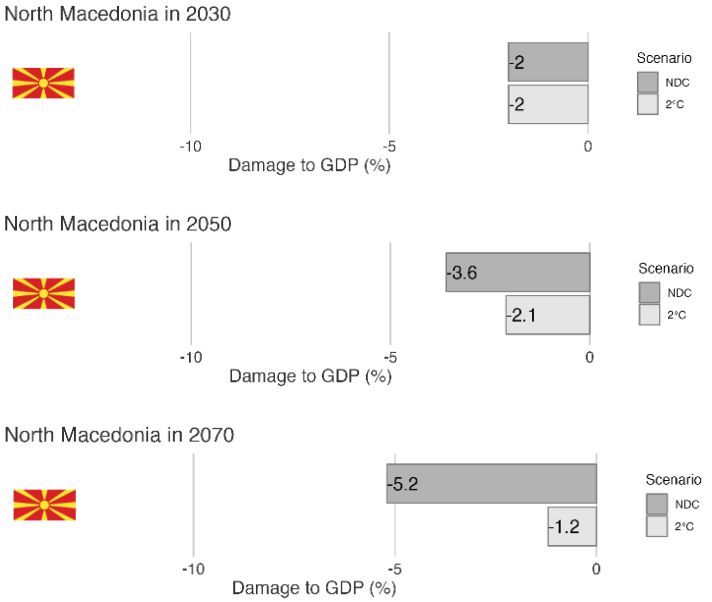
The projected impacts from climate change on Bosnia and Herzegovina make the country increasingly vulnerable to heat waves, heavy precipitation and landslides. The most common weather extremes are associated with heavy rainstorms that may cause mudslides and flooding of large areas of agricultural land, homes and industrial buildings and lead to other changes in the environment. Droughts may become more frequent in some areas due to river runoff decrease or drying in the country's lowland areas as well as from increased demand and consumption from economic development and population growth. Climate change is expected to increase risks and severity of extreme weather events through more intense temperatures as well as rainfall patterns, prolonged heat waves, and water scarcity.[46]

Climate policies

Bosnia and Herzegovina's energy sector relies mostly on fossil fuels, with a huge coal sector. It is well endowed with renewable energy resource potential; however, the sector is still in its initial stage of development. The International Renewable Energy Agency says it has significant potential for solar and wind power.[47]

Bosnia and Herzegovina submitted its revised NDC in April 2021. It updated its conditional greenhouse gas emissions reduction target to 36.8% below 1990 levels by 2030. The country also increased the unconditional greenhouse gas emissions reduction target to 33.2% by 2030 compared to 1990 levels, 18% more than in the initial NDC.[48] The revised NDC sets long-term greenhouse gas emissions reduction targets for 2050 at 61.7% (unconditional) and 65.6% (conditional) below 1990 levels. For the first time, Bosnia and Herzegovina included adaptation priorities and actions in the NDC.[49]

North Macedonia



Climate impacts

North Macedonia is exposed to climate-related hazards that pose substantial risks to public safety and public infrastructure. Analysis by the IMF last year found that between 1990 and 2023, flooding events were the most frequent extreme weather events and caused the largest damages, totalling $644 million. However, the largest impact on the population was caused by forest fires, which affected over one million people between 1990 and 2023. Over a year, there is more than 50% probability of experiencing weather conditions which could support a significant wildfire resulting in property and life loss.[50]

Floods and fires are forecast to become more frequent and extreme as climate change alters temperatures and climate patterns. The country is highly exposed to river floods and urban flooding. Potentially damaging and life-threatening floods are likely to occur at least once in the next 10 years. Wildfires and landslides are two other areas of high risk. Climate change is expected to pose greater risks to North Macedonia in the future.

Climate policies

North Macedonia was the first country in the region to adopt a National Energy and Climate plan outlining the path to achieving goals set for 2030. In the enhanced Nationally Determined Contribution (NDC) submitted in 2021 the government committed to reduce GHG emissions by more than 50% by 2030 compared to 1990.

North Macedonia has an aging fossil fuel-based energy generating infrastructure and potentially a large scope for improving energy efficiency. North Macedonia is a relatively energy-intensive economy with a fossil fuel-dominated energy mix, driving the country's greenhouse gas emissions. Coal-based electricity generation accounts for 50% of total domestic electricity production. Serious issues with air quality and the overall emissions – as well as scope for greater energy efficiency – are created by the aging coal-fired power plants, some of which from the 1960s, intensive use of inefficient electrical resistance heating devices, and heating stoves on fuelwood and coal, as well as a relatively high pollution from the transport sector.[51]

A note on methodology

Existing literature on the impacts of climate change on economic performance and activity consistently show that the economic costs of climate change are likely to be substantial and far-reaching, affecting countries across the globe. Most recent studies highlight that even in the near term, the world economy is committed to significant income reductions due to historical emissions and socio-economic inertia (Kotz et al., 2024). However, to date, there has been no consensus in the literature on what the single best approach to estimate economic damages of climate change is. In the analysis underlying this report, we combine state-of-the-art approaches from peer-reviewed literature (Burke et al., 2015; Waidelich et al., 2024; Kotz et al., 2024). The three studies are similar in the basics of their statistical approaches but differ in several assumptions and selections of climate variables, as described below. For more detail, please refer to the Appendix.

Recommendations

- **The 'finance COP' must deliver.**
  COP29 has been dubbed the 'finance COP'. The current UNFCCC finance deal – that rich (Annex II countries) would transfer $100bn in climate finance to 'developing countries' annually between 2020 and 2024 – is expiring and there is a chronic need for climate finance in many of the poorest parts of the world. Last year's COP28 in Dubai made little progress on this which is why the buck must now stop in Baku with a clear long term finance goal set for richer, polluting countries to deliver finance to those in need. Instead of a politically convenient target, governments at COP29 must agree a new finance goal based on needs. This money must predominantly be in the form of grants, not

loans, otherwise it will just exacerbate the debt crisis in much of the global south. Private finance has little role in adaptation and no role in paying for Loss and Damage.

- **Boosting the global energy transition from dirty to clean**
  We need to see this COP laying the groundwork for countries to strengthen their Nationally Determined Contributions (NDCs) to accelerate the transition away from fossil fuels towards clean energy. As a major oil and gas producer Azerbaijan has a vital role to play in this. The more fossil fuels it generates, the greater the economic pain will be to itself and its neighbours in the region.

- **Raising ambition on emissions cuts**
  Countries must publish updated (NDCs) by February 2025. These need to be much more ambitious than existing plans since the UN forecasts that current policies and plans will lead to 2.8C (or 3.1C) of warming, much higher than the Paris Agreement target of keeping warming 'well below 2C' and hence risking the kind of economic and other catastrophic impacts highlighted in this report. COP29 needs to generate momentum for Paris-aligned NDCs with countries demonstrating greater ambition and rich countries agreeing to provide increased finance to 'developing countries'.

Appendix

Methodology

Extant literature on the impacts of climate change on economic performance and activity consistently show that the economic costs of climate change are likely to be substantial and far-reaching, affecting countries across the globe. Most recent studies highlight that even in the near term, the world economy is committed to significant income reductions due to historical emissions and socio-economic inertia (Kotz et al., 2024).

However, to date, there has been no consensus in the literature on what the single best approach to estimate economic damages of climate change is. The damages can be estimated both by assessing impacts in a bottomup way (aggregating specific impacts such as labour force productivity losses, agricultural losses, infrastructure damages) or in a top-down fashion, by estimating a statistical relationship between climatic variables and economic performance. Within each category, a variety of approaches have been proposed.

In the analysis underlying this report, we combine three top-down approaches from peer- reviewed literature (Burke et al., 2015; Waidelich et al., 2024; Kotz et al., 2024). All three studies are similar in the basics of their statistical approaches but differ in several assumptions and selections of climate variables, as described below. They all use econometric panel data methods, specifically the so-called fixed effects models. Panel data refers to datasets that contain multiple observations for an entity (e.g., countries or subnational regions) over time. Fixed effects models are used to account for unobserved, time-invariant characteristics of entities that might influence the outcome variable. By using fixed effects, the risks of confounding information and omitted variable bias are minimized.

The approach proposed by Burke et al. (2015, 2018) estimates a historical relationship between GDP growth and temperature, with a non-linear regression model that allows for different effects in high-income vs. lowincome countries. In 2024, two publications extended the approach of Burke et al. The approach by Waidelich et al. (2024) highlighted the need to account for the effect of precipitation in estimating economic damages. To capture uncertainties related to temperature and precipitation variability, the authors propose to test four additional indicators: 1) daily temperature variability (how much daily temperatures deviate from monthly means); 2) extreme precipitation (the annual amount of precipitation on days with exceptionally high precipitation); 2) monthly precipitation deviation (how much monthly precipitation differs from historical averages and 4) the annual number of 'wet days' (days with precipitation above 1 mm). Kotz et al. (2024) proposed a model that utilizes subnational data to exploit within-region variation in climatic and economic variables. Additionally, this analysis includes six climate variables: 1) average annual temperature, 2) daily temperature variability, 2) total annual precipitation, 3) the annual number of wet days and 4) extreme daily precipitation that occur in addition to those already identified from changing average temperature.

More broadly, one of the most prominent differences in assessments of economic damages from climate change stems from the choice between estimating damage to the level of output in an economy (i.e., impact on GDP in a single year or at a point in time) or whether it impacts economic growth (i.e., impact on GDP growth via damages to natural and human capital, under-investment, etc.), and if so, how persistent is the effect on growth. Resulting estimates from the two approaches vary primarily because the growth effects accumulate over time and are, by definition, substantially larger than level effects. To date, there is no consensus on this issue. Growth-based effects from prominent global assessments based on top-down econometrics result in larger cumulative effects than the level effects, as growth effects compound over time.

The three studies here assess growth impacts, but they differ in their assumptions on how permanent or persistent the effects on growth are. Burke et al. (2015, 2018) assume that the effects on growth are permanent and persist over time. Kotz et al. (2024) empirically detect the persistence in the effects on economic growth and find approximately 8–10 years of persistence for the temperature variables and up to approximately 4 years for the precipitation variables. Waidelich et al. (2024) assume no persistence in the effects on GDP growth.

As the results vary depending on the exact model specification and included variables, throughout the report we show central estimates (averages of the three above mentioned models).

In all approaches, the historical relationship is extended to different pathways of climate variables over the 21st century to estimate how GDP growth might be affected by climate change. We compare two synthetic temperature pathways: a pathway consistent with likely chance (>67%) of limiting the global mean temperature increase to 2C and a pathway consistent with global mean temperature increase based on the emissions aligned with the Nationally Determined Contributions (NDCs), which are projected to lead to approximately 2.8C mean temperature increase by 2100. These temperature pathways were derived from two respective subsets of scenarios in the AR6 Scenarios Database used for the IPCC 6 Assessment Report, as presented in Fig SPM.4 of the Summary for Policymakers. We take the mean global surface air temperature variable (50% likelihood) across these scenarios to generate the two synthetic pathways.

The original GDP impacts results for each country through time (based on Burke et al, 2018) were subsequently mapped to global warming levels into piecewise linearly interpolated look-up tables, from which the mean impact (across the available scenarios) is calculated . For the 2C and NDC pathways, the global mean temperatures in 2030, 2050 and 2070 (see Table 1) are then used to identify the GDP impacts in each country.

Scenario	2030	2050	2070
2DC	1.47 □C	1.69 □C	1.69 □C

NDC	1.47 □C	1.94 □C	2.30 □C

Future GDP growth in the climate change scenarios is compared to the "baseline" scenarios available from the socio-economic scenario framework – the Shared Socioeconomic Pathways (SSPs) (O'Neill et al. 2017) – which are the basis for climate impact assessments in the 6th Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC). The SSPs are meant to represent a range of plausible futures of socioeconomic components in a hypothetical world without climate change. They are used as baselines in comparisons to scenarios with climate change. Here we compare the climate-affected estimates with the GDP estimates based on a SSP2 scenario which is meant to represent the continuation of the current trends.

It is important to note that none of the approaches used here account for changes in adaptation patterns in the future. In other words, all three approaches share the assumption that future adaptation rates mirror the historical ones. Accounting for different levels of adaptation in the future.

For detailed methodological approaches, please refer to the original publications:

1. Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. Nature, 527(7577), 235-239.
2. Burke, M., Davis, W. M., & Diffenbaugh, N. S. (2018). Large potential reduction in economic damages under UN mitigation targets. Nature, 557(7706), 549-553.
3. Kotz, M., Levermann, A., & Wenz, L. (2024). The economic commitment of climate change. Nature, 628(8008), 551-557.
4. Waidelich, P., Batibeniz, F., Rising, J., Kikstra, J. S., & Seneviratne, S. I. (2024). Climate damage projections beyond annual temperature. Nature Climate Change, 1-8.

Other literature:

1. O'Neill, B. C., Kriegler, E., Ebi, K. L., Kemp-Benedict, E., Riahi, K., Rothman, D. S., ... & Solecki, W. (2017). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. *Global environmental change*, *42*, 169-180.
2. IPCC, 2023: Summary for Policymakers. In: *Climate Change 2023: Synthesis Report.* Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001.

End Notes

1 https://climateactiontracker.org/publications/azerbaijan-country-assessment-september-2024/

9 https://climateactiontracker.org/publications/azerbaijan-country-assessment-september-2024/

15 https://www.undp.org/montenegro/projects/climate-promise-initiative#:~:text=Project%20Outcome-in-improving-azerbaijans-cotton-productivity

ns/azerbaijan-country-assessment-
2 https://climate.ec.europa.eu/climate-change/consequences-climate-change_en#:~:text=Temperature%20extremes%20are%20projected%20to,and%2https://www.nature.org/en0more%20frequent%20forest%20fires.
3 https://documents1.worldbank.org/curated/en/099112723161524095/pdf/P1790480Significant%20Step%20Toward%20Achieving%2050%25%20Renewable%20Energy%20Target%20by%202030&text=To%20accelerate%20its%20shift%20to,Accelerate%20Downed%20oil%20and,Union%20by%20eration%20(MEGA)%20national%20study2017%25%20by%202026.
4 https://unece.org/sites/default/files/2024-06/16_Montenegro_Bajic_28.5.pdf
5 https://www.adb.org/sites/default/files/publication/707466/climate-risk-country-profile-azerbaijan.pdf
6 https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjXoYTxxMCJAxX0UkEAHT3mOmkQFnoECBUQAQ&url=https%3A%2F%2Fwww.ebrd.com%2Fdocuments%2Fcountry-offices%2Fmontenegro-green-economy-transition.pdf&usg=AOvVaw1fCBYpjaVbJ9964/13/8/270#:~:text=With%20warm%2cyTnKfeMYyU&opi=89978449
7 https://www.nature.com/articles/s43247-020-00075-6
8 https://www.iaea.org/newscenter/news/climate-smart-agriculture-shows-promise-
9 https://www.climatechangenews.com/2024/05/17/azerbaijan-pursues-clean-energy-to-export-more-god-given-gas-to-europe/
10 https://www.mdpi.com/2220-9964/13/8/270#:~:text=With%20warm%2cyTnKfeMYyU&opi=89978449
11 https://www.theguardian.com/environment/2024/oct/23/cop29-host-azerbaijan-set-for-major-fossil-gas-expansion-report-says#:~:text=Azerbaijan%27s%20state%20accelerate%20its%20shift%20to,Accel2Downed%20oil%20and,Union%20by%2eration%20(MEGA)%20national%20stud017%25%20by%202026.
12 https://unfccc.int/resource/docs/natc/azenc2.pdf
13 https://montenegro.un.org/en/43433-our-changing-planet#:~:text=Climate%20change%20in%20Montenegro%20could,the%20end%20of%20the%20century.
14 https://www.mdpi.com/2220-9964/13/8/270#:~:text=With%20warm%2cyTnKfeMYyU&opi=89978449
16 https://www.climatechangenews.com/2024/05/17/azerbaijan-pursues-clean-energy-to-export-more-god-given-gas-to-europe/
17 https://unfccc.int/resource/docs/natc/azenc3.pdf

[18] https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiyjd2TrLaJAxWuaqQEHYF8MOIQtANegQIGRAF&url=https%3A%2F%2Fwww.imf.org%2F-%2Fmedia%2FFiles%2FPublications%2FCR%2F2022%2FEnglish%2F1ALBEA2022005.ashx%23%3A~%3Atext%3Dfrequency%2520in%2520its%2520recent%2520history%2Cgreater%2520share%2520of%2520the%2520population.&usg=AO vVaw0r-UBszH94BaykBHpIED0x&opi=89978449

[19] https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiyjd2TrLaJAxWuaqQEHYF8MOIQtANegQIGRAF&url=https%3A%2F%2Fwww.imf.org%2F-%2Fmedia%2FFiles%2FPublications%2FCR%2F2022%2FEnglish%2F1ALBEA2022005.ashx%23%3A~%3Atext%3Dfrequency%2520in%2520its%2520recent%2520history%2Cgreater%2520share%2520of%2520the%2520population.&usg=AO vVaw0r-UBszH94BaykBHpIED0x&opi=89978449

[20] https://bankwatch.org/beyond-fossilfuels/energy-sector-in-albania

[21] https://www.voltalia.com/newsreleases/news-release-details/karavastasolar-plant-produces-its-first-megawatthours

[22] https://bankwatch.org/publication/brokenrivers-impacts-european-financed-smallhydropower-plants-pristine-balkanlandscapes

[23] https://climatepromise.undp.org/whatwe-do/where-we-work/albania#:~:text=Albania%20committed%20to%20an%20unconditional,2030%20compared%20to%202016%20levels.

[24] https://climateknowledgeportal.worldbank .org/country/croatia/vulnerability

[25] https://www.preventionweb.net/news/croa tia-tackles-water-losses-improve-climateresilience

[26] https://ccpi.org/country/hrv/

[27] https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/690662/EPRS_BRI(2021)690662_EN.pdf

[28] https://climateknowledgeportal.worldbank.org/sites/default/files/2021-06/15836WB_Georgia Country Profile WEB.pdf

[29] https://climatepromise.undp.org/whatwe-do/where-wework/georgia#:~:text=Key%20highlights%20from%20the%20NDC%20*%20Georgia,and%20damages%20caused%20by%20extreme%20weather%20events.

[30] https://ndcpartnership.org/news/georgiaslow-emission-pathway-model-developingcountries

[31] https://www.sei.org/features/greengoageorgiaclimate/#:~:text=To%20enhance%20compliance%20with%20European,47%25%20compared%20to%201990%20levels.

[32] https://www.iea.org/articles/hungarycl resilience-policy-indicator

[33] https://climateknowledgeportal.worldbank.org/country/hungary#:~:text=Hungary%20is%20a%20market%20economy,vulnerable%20to%20the%20climate%20chang e.

[34] https://www.adaptation-undp.org/explore/europe-and-centralasia/hungary#:~:text=Drought%20has%20been%20identified%20as,part%2C%20from%20water%20management%20issue s.

[35] https://ccpi.org/country/hun/

[36] https://www.preventionweb.net/publicatio n/seclimate-chante-adaptationprogramme-period-2030#:~:text=Climate%20change%2C%20which%20is%20occurring,for%20the%20Republic%20of%20Serbia.

[37] https://www.agroberichtenbuitenland.nl/actueel/nieuws/2024/07/12/serbia-climatechangtaking-its-toll-on-theenviornment-and-onagriculture#:~:text=Droughts%20have%20caused%20severe%20damages&text=Regions%20that%20once%20experienced%20regular,Djurdjevic%20emphasized%20to%20Nova%20Ekonomija.

[38] https://www.sciencedirect.com/science/article/abs/pii/S0301421524001575

[39] https://www.irena.org/-/media/Files/IRENA/Agency/Statistics/Sta