12

SECTION

Thematic Reviews

12.1. Climate Change

State of Climate in 2023

According to WMO annual report, 2023 was the warmest year on record. Records were once again broken, and in some cases smashed, for greenhouse gas levels, surface temperatures, ocean heat and acidification, sea level rise, Antarctic sea ice cover and glacier retreat. 2023 has shown that ongoing climate change is having an increasing impact on our planet.

Key messages

Temperature. 2023 was the warmest year in the 174-year observational record: the global mean near-surface temperature in 2023 was 1.45 ± 0.12 °C above the 1850-1900 average. It also clearly surpassed the previous joint warmest years, 2016 at 1.29 ± 0.12 °C above the 1850-1900 average and 2020 at 1.27 ± 0.13 °C. The long-term increase in global temperature is due to increased concentrations of greenhouse gases in the atmosphere. The shift from La Niña to fully developed El Niño conditions in mid-2023 likely explains some of the rise in temperature from 2022 to 2023.

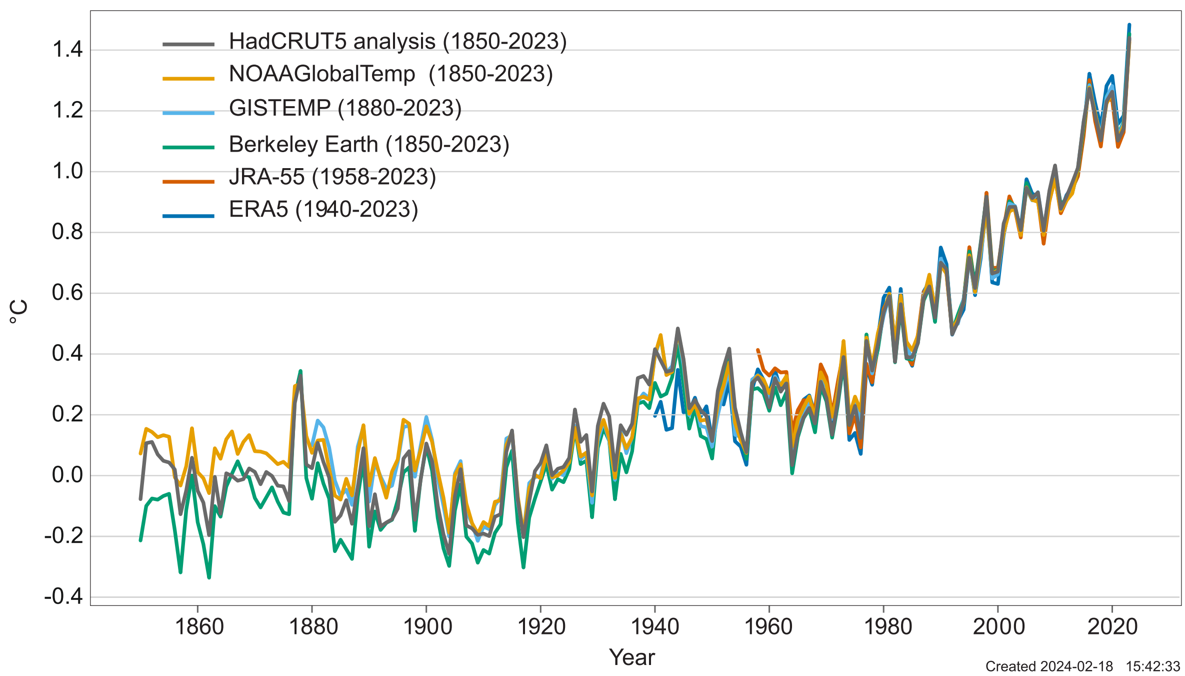
Greenhouse gases. Concentrations of the three main greenhouse gases – carbon dioxide, methane and nitrous oxide – reached record-high observed levels in 2022 and continued to increase in 2023.

Glaciers. 2023 showed the largest loss of ice on record (1950-2023), driven by extremely negative mass balance in both western North America and Europe. Glaciers in western North America and the European Alps experienced an extreme melt season. In Switzerland, glaciers have lost about 10% of their remaining volume in the past two years. Western North America experienced record glacier mass loss at rates that were five times higher than rates measured for the period 2000-2019. Glaciers in western North America lost an estimated 9% of their 2020 volume over the period 2020-2023.

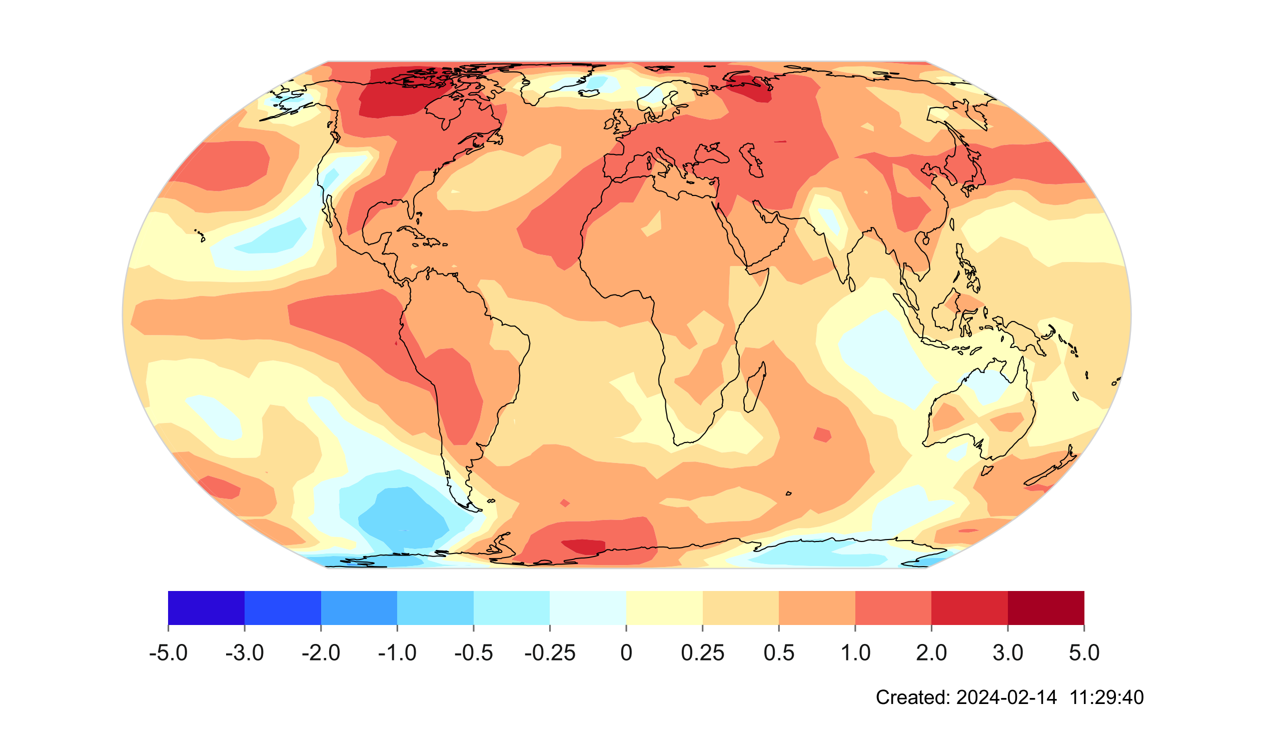
Ocean. In 2023, ocean heat content reached its highest level. It is expected that warming will continue – a change that is irreversible on centennial to millennial timescales.

Most of the global ocean from roughly 20°N to 20°S of the equator had been in a marine heatwave state since early November. Of note in 2023 were the persistent and widespread marine heatwaves in the North Atlantic, which began in the northern hemisphere spring, peaked in extent in September and persisted through the end of the year, with temperature anomalies in the open ocean of +3°C. The Mediterranean Sea experienced near-complete coverage of strong and severe marine heatwaves for the twelfth consecutive year.

Annual global mean temperature anomalies *(relative to 1850-1900)*.
Data are from the six datasets indicated in the legend.



Mean near-surface temperature anomalies *(difference from the 1991-2020 average)* for 2023. Data are the median of the six datasets indicated in the legend



The ocean acidification increases as a result of absorption of CO_2.

Sea level. In 2023, global mean sea level reached a record high in the satellite record (from 1993 to present), reflecting continued ocean warming as well as the melting of glaciers and ice sheets.

The rate of global mean sea-level rise in the past 10 years (2014-2023) is more than twice the rate of sea-level rise in the first decade of the satellite record (1993-2002).

Socio-economic and environmental impacts

Extreme weather had major impacts on all inhabited continents in 2023.

Long-term **drought** persisted in North-western Africa and parts of the Iberian Peninsula, as well as in parts of Central and South-West Asia, and intensified in many parts of Central America, northern South America and the southern United States. In Uruguay, water storages reached critically low levels, badly affecting the quality of supplies to major centers, including Montevideo.

Flooding. Flooding associated with extreme rainfall from Mediterranean Cyclone Daniel affected Greece, Bulgaria, Türkiye and Libya. Tropical Cyclone Freddy in February and March was one of the world's longest-lived tropical cyclones impacting severely Madagascar, Mozambique and Malawi.

Heatwaves. Many significant heatwaves occurred in various parts of the world, especially in the second half of July, when severe and exceptionally persistent heat occurred in southern Europe and North Africa, including: 48.2°C in Italy; 49.0°C in Tunis; 50.4°C in Morocco; 49.2°C in Algeria. This caused extensive wildfire activity during the summer, particularly in Greece, where 96,000 ha were burned.

The deadliest single wildfire of the year occurred in Hawaii, where at least 100 deaths were reported.

Food insecurity. The number of people who are acutely food insecure worldwide has more than doubled, from 149 million people before the COVID-19 pandemic to 333 million people in 2023. Although global hunger levels remained unchanged from 2021 to 2022. However, they are still far above pre-COVID 19 pandemic levels: in 2022, 9.2% of the global population (735.1 million people) were undernourished.

Protracted conflicts, economic downturns and high food prices are at the root of high global food insecurity levels. High food prices are exacerbated by the high costs of agricultural inputs, driven by ongoing and widespread conflict around the world, and high global food insecurity levels are aggravated by the effects of climate and weather extremes. In southern Africa, for example, weather extremes, including the passage of Cyclone Freddy, have affected areas of Madagascar, southern Malawi, Mozambique and Zimbabwe and caused severe damage on crops and economy. Afghanistan experienced a substantial reduction in snowmelt and rainfall, resulting in another poor crop season.

Between May and October, 15.3 million Afghans were estimated to face severe acute food insecurity, especially in the north and northeast of the country. The return of El Niño in 2023 led to adverse consequences through the entire crop cycle of maize in Central America and northern parts of South America, where water deficits and high temperature had negative impacts on final production, particularly for smallholders and more vulnerable households in the Dry Corridor. Floods in July affected the main cropland areas in Libya, which was already in a state of food crisis and in need of external assistance.

Climate and Water Resources

Record temperatures across most of the world in 2023 also affected the global water cycle, from intensifying cyclones and other rainfall systems, to exacerbating drought and fire activity. In 2023, the Global Water Monitor Consortium[369] published its second annual report.

Key messages

Precipitation was close to average. There does not appear to be a clear trend towards more monthly high or low rainfall extremes. However, total precipitation in 2023 was unusually high in some regions at high northern latitudes (including Arctic Canada and parts of northern Europe), the Arabian Peninsula, the Horn of Africa, south Asia and the Himalayas.

Rainfall was unusually low in the southern half of Canada, Central America, the north and east of South America, the western Mediterranean, and Central Asia. Annual rainfall was unusually low in Mexico, Turkmenistan and Marocco ($\sigma<-2$).

The lowest annual rainfall since 1979 was recorded for six river basins in Canada, the Sao Francisco River in eastern Brazil, along the Central American coast, the Aral Basin. Record high annual precipitation was observed in several Arctic basins, as well as river catchments in Sweden and the Tibet Plateau.

Air humidity. Air humidity over land was the second lowest on record, continuing a trend towards drier average and extreme conditions. A total of 20 countries and territories experienced unusually low air humidity ($\sigma<-2$) in 2022. They include Russia, Turkmenistan and Uzbekistan in Central Asia, five countries and territories in the Caribbean, five in South America (including Brazil), three in North-Africa, Sudan and South Sudan in Eastern Africa.

Soil water. Despite warmer and drier conditions, high annual soil water conditions were observed in many regions, with relatively wet soils across Europe, South and Eastern Asia, the western USA and Northern Australia.

Very dry soil conditions occurred in Central Asia (especially in Turkmenistan), the south of South America and in some regions in high northern latitudes.

Surface water occurrence. In 2023, global surface water occurrence was the second lowest in two decades, but months with record high water occurrence appear to be increasing globally. Annual water occurrence was average or below average in most countries. Water extent was unusually low for Turkmenistan due to ongoing water level declines in the Caspian Sea and in the Falkland Islands. Water occurrence was extremely high in Ethiopia, South Sudan and Egypt due to high rainfall in the Upper Nile. Water occurrence was also unusually high in 14 other countries, including India and Nepal in Asia, Guinea-Bissau and Chad in Africa, Cuba and several smaller island states.

River flows. In 2023, global river flows were slightly lower than the previous year. River flows were: (1) extremely high in both Congo's and unusually high and/or the highest since 2003 in Nigeria, the Central African Republic and Ethiopia in Africa, the UK, Ireland and Denmark in Europe, El Salvador and Ecuador in the Americas, Iran and Azerbaijan in Asia, and in New Zealand; (2) low and/or the lowest since 2003 in Georgia, Bhutan and Myanmar in Asia and Colombia in South America.

Terrestrial water storage[370] was unusually low in much of North and Central America, the Mediterranean region, North Africa, Central Asia, and parts of China and South Asia. Long-term declines in Caspian Sea level and retreating mountain glaciers play a role in some of these regions. Terrestrial water storage was unusually high in most of the northern high latitudes, as well as isolated parts of South America, Africa and Oceania.

Climate Change Agreement

As of February 2023, 198 members of UNFCCC, which represent over 98% of global GHG emissions, are parties to the Paris agreement. China and USA are the largest emitters of CO_2 among the members of the UNFCCC.[371] Since 2020, countries have been submitting their national action programs on climate

[369] the Global Water Monitor Consortium brings together several public and private research and development organisations that share a goal of providing free, rapid and global information on climate and water resources (http://www.globalwater.online/)

[270] the sum of all water on the continents, including soil water, groundwater and surface water as well as snow and ice

[371] UN Framework Convention on Climate Change

change, known as Nationally Determined Contributions (NDCs).

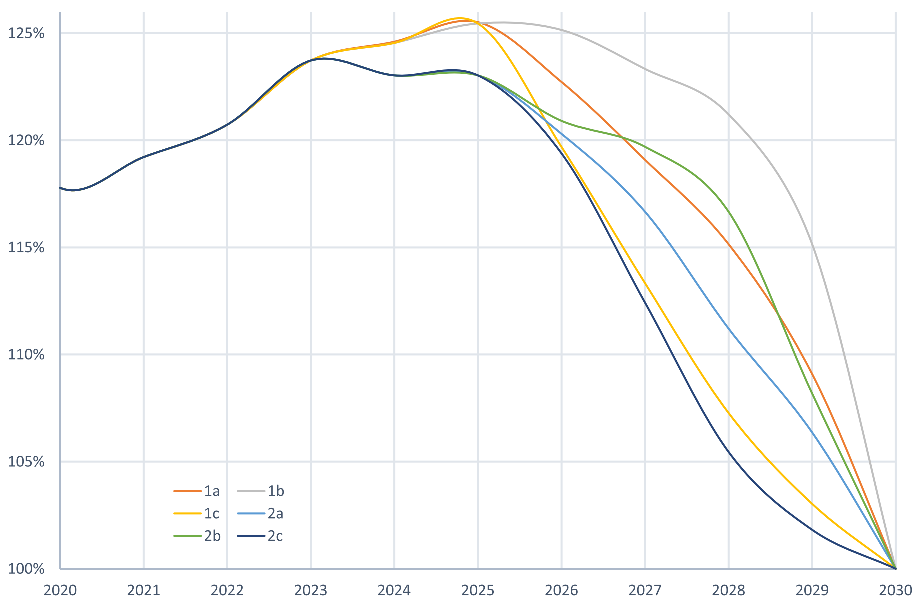
Implementation of Paris Agreement in CA

All five Central Asian countries ratified the Paris Agreement to address the climate change threats and take appropriate measures. This necessitates a profound transformation of national energy systems, requiring substantial investments in sustainable infrastructure. Crucially, achieving climate goals demands that national development plans are fully aligned with ambitious climate action targets.

Kazakhstan ratified the Paris Agreement in November 2016 and set the goal to mitigate climate change at the net zero level by adopting a carbon neutrality strategy for 2060. In 2023, Kazakhstan launched its updated NDC, which included an unconditional target of reducing GHG emissions by 15% by the end of 2030 relative to 1990 base year. The country has adopted the Development Strategy of the Republic of Kazakhstan until 2050, the Environmental Code, the Emissions trading system and the taxonomy of green projects[372] that contribute to transition to RES. Thus, the Government has set the goal that the share of RES in electricity production shell be increased to 15% by 2030 and to 50% by 2050.

Scenarios for achieving NDCs of Kazakhstan by 2030

Emission reduction projections



Assessment methods:
- CGE Macroeconomic model
- TIMES Technical-economic model
- Model of air pollution and assessment of population death risks

NDC achievement scenarios:
1. ETS enhancement, annual rate 3-4% reduction rate
   a) Uniform reduction in 2025-2030
   b) Accelerated reduction in 2028-2030
   c) Accelerated reduction in 2025-2028
2. Enhanced ETS and carbon tax annual reduction rate 2.25-2.5% (2-2-3)
   a) 5-10-30$
   b) 5-15-35$
   c) 5-20-40$

Kyrgyz Republic submitted its updated NDC in October 2021. The Republic has committed to unconditionally reduce GHG emissions by 16.63% by 2025 and by 15.97% by 2030, under the business-as-usual scenario. Should international support be provided, GHG emissions will be reduced by 36.61% by 2025 and by 43.62% by 2030. The country has developed and is implementing the following strategic documents related to the NDC: National Development Strategy of the Kyrgyz Republic for 2018-2040, Climate Investment Program of the Kyrgyz Republic and Program for the Development of a Green Economy in the Kyrgyz Republic for 2019-2023. In 2025, some adaptation measures of NDC will be revisited for 2026-2030.

Tajikistan launched its updated NDC in October 2021. In line with this NDC, the country is committed to reduce GHG emissions by 40-50% subject to an international funding by 2030 (against 1990). The unconditional contribution (NDC) of reducing GHG in Tajikistan is to reduce GHG by 30-40% by 2030 (against 1990) through enhanced adaptation in energy, water, agriculture, forestry and transport sectors. The National Development Strategy of Tajikistan until 2030, the Mid-Term Development Program (MDP) of the Republic of Tajikistan for the period of 2021-2025, the National Strategy of Tajikistan for Disaster Risk Reduction for 2019-2030 and the National Strategy for Adaptation to Climate Change until 2030 have been developed and are implemented in the country.

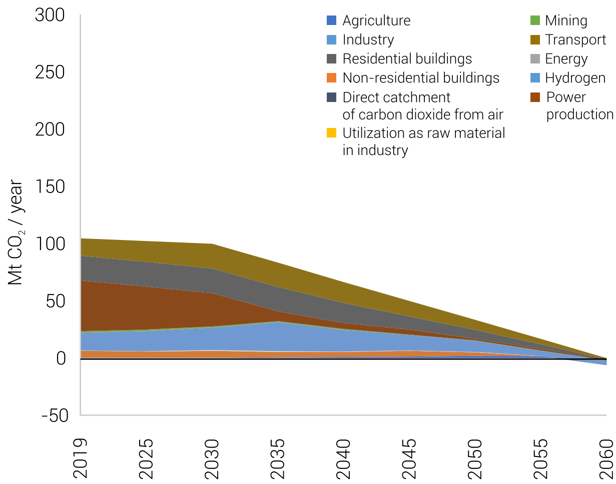
Turkmenistan in its second NDC submitted in 2022 commits to reduce GHG emissions by 20% by 2030 (against 2010). GHG emissions increased in Turkmenistan from 58.4 $MtCO_2$ in 2010 and 63 $MtCO_2$ in 2020 to 65.7 $MtCO_2$ in 2021. The specified target covers economy as a whole, including energy, industry, agriculture. It embraces CO_2, CH_4, N_2O and foamed plastic emissions.

[372] a classification framework for defining what can be called environmentally sustainable investments

Turkmenistan also declared the adaptation measures until 2030, in particular, increase resilience and reduce vulnerability to climate change to achieve sustainable economic growth. For this, the country needs about $500 million of international support.

Uzbekistan submitted the updated NDC in October 2021. The goal is to reduce by 2030 specific greenhouse gas emissions per unit of GDP by 35% from the level of 2010. This is more than in the first NDC, which outlined the reduction by 10%. The updated NDC also increases adaptation, especially in agriculture. Additionally, the country works to align the NDC with the Strategy for Transition of the Republic of Uzbekistan to a Green Economy by 2030. The NDC goals are to be achieved by increasing the share of RES in power production to 25%, deploy alternative fuel types in the transport sector, improve solid waste management, promote energy-saving technologies in all economic sectors, expand forest areas, etc.

Zero emission scenario by 2060



Climate Change Conference 28

The 28th Conference of the Parties to the UN Framework Convention on Climate Change (COP28) took place under the motto 'Climate action can't wait' in Dubai, United Arab Emirates, from November 30 to December 13, 2023. Participants from almost 200 countries have recognized the need to transit away from fossil fuel. Thus, COP28 was marked by the adoption of the UAE Consensus, an ambitious document, which addressed all key aspects of climate policy.

With this Consensus, the parties have committed to the following:

Tripling renewable energy capacity globally and doubling the global average annual rate of energy efficiency improvements by 2030

accelerating efforts towards the phase-down of unabated coal power

accelerating global efforts to develop and deploy zero-emission energy systems powered by zero- and low-carbon fuels, targeting widespread adoption well before mid-century

transitioning away from fossil fuels in energy systems, in a just, orderly and equitable manner, accelerating action in this critical decade, so as to achieve net zero by 2050 in keeping with the science

accelerating zero- and low-emission technologies, including, inter alia, renewables, nuclear, abatement and removal technologies such as carbon capture and utilisation and storage, particularly in hard-to-abate sectors, and low-carbon hydrogen production

accelerating and substantially reducing non-carbon-dioxide emissions globally, including in particular methane emissions by 2030

accelerating reductions in road transport emissions across all fronts, including by rapidly expanding infrastructure for and deploying zero- and low-emission vehicles

phasing out inefficient fossil fuel subsidies that do not address energy poverty or just transitions, as soon as possible

Other COP28 outcomes

For the first time in UNFCCC conferences, COP28 addressed such areas as **health, trade, relief, recovery and peace**. The outcomes were as follows:

- in order to work towards ensuring better health outcomes, including through the transformation of health systems to be climate-resilient, low-carbon, sustainable and equitable, and to better prepare communities and the most vulnerable populations for the impacts of climate change, the countries united and signed the COP28 UAE Declaration on Climate and Health;

- The loss and damage fund designed to support climate-vulnerable developing countries was brought to life[373]; countries have pledged $3.5 billion to replenish the resources of the Green Climate Fund. At the GCF's High-level Pledging Conference in Bonn in October 5, 2023, 25 countries pledged their support to GCF totaling $9.3 billion;

- COP28 Presidency also launched the UAE Declaration on Sustainable Agriculture, Resilient Food Systems, and Climate Action; more than $2.5 billion has been mobilized by the global community to support food security and the UAE and the Bill & Melinda Gates Foundation launched a partnership for Food Systems, Agriculture Innovation and Climate Action;

- 72 countries and 39 organizations joined the newly created Coalition for High Ambition Multilevel Partnership (CHAMP) for Climate Action. The Coalition aims to enhance cooperation, where applicable and appropriate, with subnational governments in the planning, financing, implementation, and monitoring of climate strategies;

- the COP28 Gender-Responsive Just Transitions and Climate Action Partnership was launched. This partnership represents a package of commitments in support of the goals of the enhanced Lima Work Program on Gender and its Gender Action Plan. Kyrgyzstan joined the partnership among the Central Asian countries;

- 38 countries signed the UNESCO Declaration on the common agenda for education and climate change, where they committed to incorporate climate education into their NDCs and national adaptation plans. Uzbekistan is one of founding partners of the Declaration;

- 43 countries and the European Union have joined the Freshwater Challenge, committing to conserve and restore 30% of degraded freshwater ecosystems. Tajikistan joined this Challenges among the Central Asia countries.

Central Asian countries at COP28

For the CA countries COP28 has started from the presentation of the Regional Climate Change Adaptation Strategy for Central Asia. The document outlines four strategic objectives: (1) strengthen regional coordination for climate change; (2) create mechanisms for the development and implementation of adaptation projects/programs and attraction of financing; (3) improve adaptive capacity through accumulation and sharing of knowledge and scientific cooperation; (4) develop climate monitoring, information exchange and forecasting systems.

During the 10^{th} meeting of representatives from the MFAs and Parliamentarians of Central Asian countries, a regional statement on combating climate change was presented. This statement holds significant importance for the countries of the region and the global negotiation process. It strengthens the collective voice of the region, promotes regional cooperation and partnerships, demonstrates a shared commitment, and enhances the effectiveness of global negotiations.

Climate Change Reports

WMO has published the Global Climate 2011-2020: A Decade of Acceleration report. This multi-agency effort provides a summary of the state of climate, extreme events and their socio-economic impacts from 2011-2020. The 2011-2020 report is the second in the series of the report, following the first decadal analysis from 2001-2010.

IPCC has released its sixth assessment report, AR6 Synthesis Report: Climate Change 2023. The report highlights the shrinking window of opportunity to limit global temperature rise to 1.5°C and the escalating climate-related risks. Global temperatures could increase by up to 4°C, leading to severe consequences such as heightened water scarcity, food shortages, and declines in well-being and health. Addressing these challenges requires transitioning away from fossil fuels and significantly increasing investments in renewable energy.

10 New Insights in Climate Science 2023/2024

1. Overshooting 1.5°C is fast becoming inevitable. Keeping global mean temperature rise within 1.5°C is only possible in the near term with immediate, transformative action that rapidly decarbonises the economy, energy and land-use systems, cutting emissions by 43% by 2030 relative to 2019 levels.

2. A rapid and managed fossil fuel phase-out is required to stay within the Paris Agreement target range.

[373] the total amount of pledges is $661 million as of January 2024

Governments and the private sector must stop enabling new fossil fuel projects, accelerate the early retirement of existing infrastructure, and rapidly increase the pace of renewable energy deployment. High-income countries must lead the transition and provide support for low-income countries.

3. Robust policies are critical to attain the scale needed for effective carbon dioxide removal (CDR). Meeting the Paris Agreement's targets will require scaling up CDR from a current level of about 2 billion tonnes of CO_2 to at least 5 billion tonnes or more by 2050. Today, virtually all CDR consists of afforestation and reforestation. Only 0.1% of current removals come from the rest of deployed methods, such as direct air capture and storage, bioenergy with carbon capture and storage, enhanced weathering, etc. However, almost all scenarios that limit warming to 1.5°C or 2°C rely on large-scale deployment of these CDR methods.

4. Over-reliance on natural carbon sinks is a risky strategy: their future contribution is uncertain. Until now, land and ocean carbon sinks have grown in tandem with increasing CO_2 emissions, but research is revealing that carbon sinks may well absorb less carbon in the future than has been presumed from existing assessments. Therefore, emission reduction efforts have immediate priority, with nature-based solutions serving to increase carbon sinks in a complementary role to offset hard-to-abate emissions.

5. Joint governance is necessary to address the interlinked climate and biodiversity emergencies. The international conventions on climate change and biodiversity must find better alignment. Ensuring that the allocation of climate finance has nature-positive safeguards, and strengthening concrete cross-convention collaboration, are examples of key actions in the right direction.

6. Compound events amplify climate risks and increase their uncertainty. "Compound events" refer to a combination of multiple drivers and/or hazards (simultaneous or sequential), and their impacts can be greater than the sum of individual events. Crops are particularly sensitive to the simultaneous occurrence of extreme hot and dry conditions. Early spring followed by a late frost, can also harm crops. Given that a large proportion of crops are grown in just a few breadbasket regions, global food security is threatened. Therefore, identifying and preparing for specific compound events is crucial for robust risk management and providing support in emergency situations.

7. Mountain glacier loss is accelerating. New global glacier projections estimate that glaciers will lose between 26% (at +1.5°C) and 41% (at +4°C) of their current volume by 2100. This threatens populations downstream with water shortages in the longer term (approximately 2 billion worldwide), and exposes mountain dwellers to increased hazards, such as flash flooding.

8. Human immobility in areas exposed to climate risks is increasing. People facing climate risks may be unable or unwilling to relocate, and existing institutional frameworks do not account for immobility and are insufficient to anticipate or support the needs of these populations.

9. New tools to operationalize justice enable more effective climate adaptation. Monitoring the distinct dimensions of justice and incorporating them as part of strategic climate adaptation planning and evaluation can build resilience to climate change and decrease the risk of maladaptation.

10. Reforming food systems contributes to just climate action. Food systems are responsible for 31% of global GHG emissions and are capable of pushing global warming towards 2°C by 2100 barring significant changes to the status quo. At the same time, over 700 million people face hunger, and marginalised groups are disproportionately affected by food insecurity. Sustainability transformations research shows that fundamental food systems change might take decades, so action cannot be delayed any further. Sufficiency, regeneration, distribution, commons and care are guiding principles to steer the restructuring of food systems.

Source: 10NICS-2023-Report_digital.pdf

UNEP has published the 14th edition of the Emissions Gap Report for 2023 entitled "Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again)". The report concludes that 2023 was marked by broken records and unmet commitments: greenhouse gas emissions remain high, global temperatures reached unprecedented levels, and the impacts of climate change are intensifying and accelerating. Moreover, financial resources intended to support vulnerable communities in adapting to climate change remain undisbursed.

Key messages:

1. Global GHG emissions set new record of 57.4 $GtCO_2e$ in 2022.[374] Global GHG emissions increased by 1.2% from 2021 to 2022 to reach a new record of 57.4 $GtCO_2e$. Global primary energy consumption expanded mainly through a growth in coal, oil and renewable electricity supply – whereas gas consumption declined by 3% following the energy crisis and the war in Ukraine. Investments in fossil fuel extraction and use have continued in most regions worldwide.

2. Current and historical emissions are highly unequally distributed within and among countries, reflecting global patterns of inequality. Per capita territorial GHG emissions vary significantly across countries. They are

[374] gigatons of CO_2 equivalent

more than double the world average of 6.5 tons of CO_2 equivalent (tCO_2e) in the Russian Federation and the United States of America, while those in India remain under half of it.

3. There has been negligible movement on NDCs since COP27, but some progress in NDCs and policies since the Paris Agreement was adopted. If all new and updated unconditional NDCs are fully implemented, they are estimated to reduce global GHG emissions by about 5.0 $GtCO_2e$ annually by 2030, compared with the initial NDCs. The combined effect of the nine NDCs submitted since COP27 amounts to around 0.1 $GtCO_2e$ of this total. Thus, while NDC progress since COP27 has been negligible, progress since the adoption of the Paris Agreement is more pronounced, although still insufficient to narrow the emissions gap.

4. The number of net-zero pledges continues to increase, but confidence in their implementation remains low. As at 25 September 2023, 97 Parties covering approximately 81% of global GHG emissions had adopted net-zero pledges either in law (27 Parties), in a policy document such as an NDC or a long-term strategy (54 Parties), or in an announcement by a high-level government official (16 Parties). Responsible for 76 per cent of global emissions, all G20 members except Mexico have set net-zero targets. However, most concerningly, none of the G20 members are currently reducing emissions at a pace consistent with meeting their net-zero targets.

5. The emissions gap in 2030 remains high: current unconditional NDCs imply a 14 $GtCO_2e$ gap for a 2°C goal and a 22 $GtCO_2e$ gap for the 1.5°C goal. The additional implementation of the conditional NDCs reduces these estimates by 3 $GtCO_2e$. The emissions gap is defined as the difference between the estimated global GHG emissions resulting from full implementation of the latest NDCs and those under least-cost pathways aligned with the long-term temperature goal of the Paris Agreement. The emissions gap for 2030 remains largely unchanged compared with last year's assessment. Full implementation of unconditional NDCs is estimated to result in a gap with below 2°C pathways of about 14 $GtCO_2e$ (range: 13-16) with at least 66% chance.

6. Action in this decade will determine the ambition required in the next round of NDCs for 2035, and the feasibility of achieving the long-term temperature goal of the Paris Agreement. Global ambition in the next round of NDCs must be sufficient to bring global GHG emissions in 2035 to the levels consistent with below 2°C and 1.5°C pathways of 36 $GtCO_2e$ (range: 31-39) and 25 $GtCO_2e$ (range: 20-27) respectively, while also compensating for excess emissions until levels consistent with these pathways are achieved. In contrast, a continuation of current policies and NDC scenarios would result in widened and likely unbridgeable gaps in 2035.

7. If current policies are continued, global warming is estimated to be limited to 3°C. Delivering on all unconditional and conditional pledges by 2030 lowers this estimate to 2.5°C, with the additional fulfillment of all net-zero pledges bringing it to 2°C. Even in the most optimistic scenario, the chance of limiting global warming to 1.5°C is only 14%, and the various scenarios leave open a large possibility that global warming exceeds 2°C or even 3°C. This further illustrates the need to bring global emissions in 2030 lower than levels associated with full implementation of the current NDCs, to expand the coverage of net-zero pledges to all GHG emissions and to achieve these pledges.

8. The failure to stringently reduce emissions in high-income countries and to prevent further emissions growth in low- and middle-income countries implies that all countries must urgently accelerate economy-wide, low-carbon transformations to achieve the long-term temperature goal of the Paris Agreement. Energy is the dominant source of GHG emissions, currently accounting for 86% of global CO_2 emissions. Global transformation of energy systems is thus essential, including in low- and middle-income countries, where pressing development objectives must be met alongside a transition away from fossil fuels.

9. Low- and middle-income countries face substantial economic and institutional challenges in low-carbon energy transitions, but can also exploit opportunities. Access to affordable finance is therefore a prerequisite for increasing mitigation ambition in low- and middle-income countries. Yet, costs of capital are up to seven times higher in these countries compared with the United States of America and Europe. International financial assistance will therefore have to be significantly scaled up from existing levels, and new public and private sources of capital better distributed towards low-income countries, restructured through financing mechanisms that lower costs of capital. These include debt financing, increasing long-term concessional finance, guarantees and catalytic finance.

10. Further delay of stringent global GHG emissions reductions will increase future reliance on CDR[375] to meet the long-term temperature goal of the Paris Agreement. CDR is necessary to achieve the long-term goal of the Paris Agreement as reaching net-zero CO_2 emissions is required to stabilize global warming, whereas net-zero GHG emissions will result in a peak and decline in global warming. CDR is already deployed today – mainly in the form of conventional land-based methods, such as afforestation, reforestation and management of existing forests, with a large share located in developing countries. Present-day direct removals through conventional land-based methods are estimated to be 2.0 (±0.9) $GtCO_2$ annually, almost entirely through conventional land-based methods.

[375] carbon dioxide removal

Significant and Major Events

The UNGA adopted a resolution that asks the International Court of Justice for **an opinion on whether countries have a legal duty to address climate change** and what the legal consequences of climate inaction could be. The resolution came as a growing number of people around the world turned to courts to compel governments and businesses to act on climate change.

Global trends in climate change litigation. Climate-related lawsuits have more than doubled since 2017 according to the Global Climate Litigation Report: 2023 Status Review. While most cases have been brought in the US, climate litigation is taking root all over the world, with about 17 per cent of cases now being reported in developing countries, including Small Island Developing States.

34 cases have been brought by and on behalf of children and youth under 25 years old, including by girls as young as seven and nine years of age in Pakistan and India respectively, while in Switzerland, plaintiffs are making their case based on the disproportionate impact of climate change on senior women. Globally, 55% of cases have had a climate-positive ruling.

Most ongoing climate litigation falls into one or more of six categories: 1) cases relying on human rights enshrined in international law and national constitutions; 2) challenges to domestic non-enforcement of climate-related laws and policies; 3) litigants seeking to keep fossil fuels in the ground; 4) advocates for greater climate disclosures and an end to greenwashing; 5) claims addressing corporate liability and responsibility for climate harms; and 6) claims addressing failures to adapt to the impacts of climate change.

Remarkable climate change litigation cases in 2023

105 United Nations member countries led by a Pacific Island nation Vanuatu, asked the International Court of Justice to issue an opinion that would clarify the rights and responsibilities of states with regard to climate action. While the opinion will be nonbinding, it would clarify what obligations countries have under international law to tackle climate change and it would become more accessible for individuals to take governments to court.

A state court in Montana ruled in favor of 16 young people who had sued the state government, arguing that policies favoring fossil fuels had violated their constitutional right to a clean and healthful environment. Although the state has appealed the ruling, the verdict nevertheless marks an important precedent for those who are trying to use the legal system to address climate change.

21 youth plaintiffs in the landmark federal constitutional climate lawsuit, Juliana v. United States dismissed or delayed for over eight years, are currently moving forward toward trial on the question of whether the federal government's fossil fuel-based energy system, and resulting climate destabilization, is unconstitutional.

18 young Californians filed a case against the U.S. Environmental Protection Agency (EPA). They allege that the EPA has been allowing dangerous levels of climate pollution, thereby harming and discriminating against them.

The Native American tribes – Makah Indian Tribe and the Shoalwater Bay Indian Tribe – filed the first climate deception lawsuits against fossil fuel giants such Exxon Mobil, Shell, and others in Washington state's King County Superior Court.

Source: https://blog.ucsusa.org/delta-merner/climate-litigation-reflection-and-anticipation-for-2024/

An appeals court issued a landmark ruling in a human rights lawsuit filed by a group of Belgian citizens against the national government and regional jurisdictions. The court mandated that the Belgian government must slash carbon emissions by at least 55 percent below 1990 levels by the year 2030.

Greenpeace Nordic and Young Friends of the Earth Norway challenged the Norwegian government's approval of three new North Sea oil fields.

Six young people from Portugal – with the younger one being 11 years old- brought a lawsuit against 32 European countries, marking the first instance in which so many national governments had to defend their climate policies collectively before a court. The young plaintiffs initiated the legal action in 2020, following several years of record-breaking heat in Portugal and devastating wildfires in 2017.

Source:
https://www.sustainabilityforstudents.com/post/2023-climate-litigation-in-european-courts-recap

The Spanish Supreme Court dismissed the claim filed by the environmental associations GreenPeace España, Ecologistas en Acción-CODA and Oxfam Intermón against the Spanish government, confirming the alignment of its climate efforts with Spain's commitments under the Paris Agreement.

Five farmers have petitioned a court to compel the Kenyan Government to limit the volume of greenhouse gas emissions in Kenya by 30%. The farmers claim that the emissions are posing a threat to the earth's temperature, which is having negative side-effects in Kenya in the form of flooding, heat stress, forest fires, droughts, as well as disruption of food production and the supply of clean drinking water.

Source: https://www.nortonrosefulbright.com/en-hk/knowledge/publications/671a4943/climate-change-litigation-update-july-2023

The International Court of Justice (ICJ) was requested an advisory opinion on climate change (March 29). The UNGA in line with its resolution (A/77/L.58) initiated by the Republic of Vanuatu requested clarifications on the obligations of States with respect to climate change. For Vanuatu, similarly to other small island developing states, this is also a chance to spur transformative climate action, advance climate justice, and protect the environment for present and future generations.

An advisory opinion focuses on interpretation of the obligations in the Paris Agreement and UNFCCC and also on the human rights implications of climate change. Although ICJ advisory opinions have no binding force, given the strong reputation and legal weight of the Court, its opinion could possibly influence other courts and domestic litigation, would provide an authoritative statement on "the long-neglected matter of loss and damage" and their compensation and, finally, contribute to a more climate-sensitive global consciousness. See also International Court of Justice.

12.2. Achievement of Sustainable Development Goals

This section examines progress on selected Sustainable Development Goals (SDGs 6, 7, 13, and 15), drawing on UN reports on sustainable development.

The recent data[376] obtained at the midpoint of the 2030 Agenda for Sustainable Development indicate that many of the Goals are severely off track. The ongoing repercussions of the COVID-19 pandemic, compounded by other crises such as climate change and armed conflicts, have exerted a profound and widespread impact on poverty, food security, health, and the environment.

The Report 2023: Towards a Rescue Plan for People and Planet[377] highlights that access to drinking water, sanitation and hygiene improved significantly in rural areas, but stagnated or decreased in urban areas (SDG 6). Water use efficiency has risen by 9%, particularly in agriculture, but rising water stress in several areas is cause for concern. Central and Southern Asia experience high water stress levels, exceeding **75%**, and Northern Africa faces critical water stress, surpassing **100%**. 2.2 billion people still lack safely managed drinking water. Sub-Saharan Africa is furthest behind.

The world continues to advance towards sustainable energy targets (SDG 7) – but not fast enough. Developing countries experience **9.6%** annual growth in renewable energy installation.

With a climate cataclysm looming, the pace and scale of current climate action plans are wholly insufficient to effectively tackle climate change (SDG 13). Record-high GHG concentrations are pushing global temperatures higher, with approximately **90%** of heat being absorbed by the ocean. This is causing sea levels to rise through ice loss on land, melting glaciers and ice sheets, and thermal expansion. The rate of global mean sea-level rise has doubled in the past decade – from **2.27** mm per year in 1993-2002 to

[376] progress towards the Sustainable Development Goals: towards a rescue plan for people and planet, Report of the Secretary-General (special edition), Economic and Social Council, 78 session of UNGA

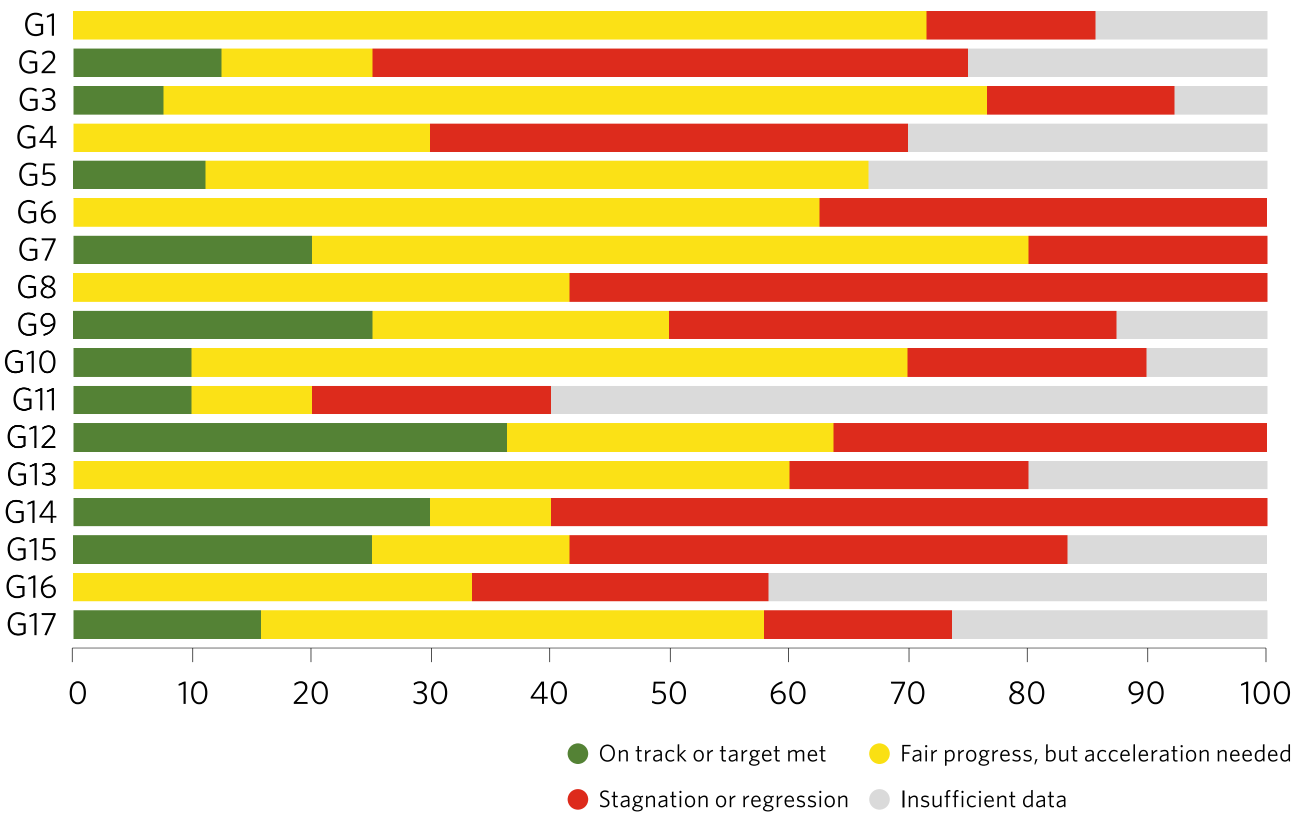
[377] The Sustainable Development Goals Report 2023: Special edition

4.62 mm per year. Even with efforts to limit warming to 1.5°C, global sea levels are expected to continue rising over the coming century, creating significant hazards for communities worldwide. This requires global climate-resilient development action, accelerated adaptation and mitigation measures, as well as appropriate finance for climate action.

Despite some progress in sustainable forest management, protected areas, and the uptake of national biodiversity values and natural capital accounting, most improvements have been modest. Deforestation and forest degradation remain major global threats. Nearly 100 million ha of net forest area have been lost over the past two decades, and global forest coverage decreased to **31.2%**. Agricultural expansion is the direct driver of almost **90%** of global deforestation (cropland accounts for **49.6%** and livestock grazing for **38.5**%). The recently adopted Kunming-Montreal Global Biodiversity Framework provides renewed impetus for Goal 15.

Progress assessment for the 17 Goals based on assessed targets is shown below. The picture is incomplete due to regular problems with obtaining timely data on all 169 targets.

Progress assessment for the 17 Goals based on assessed targets, 2023 or latest data (percentage)



Source: https://unstats.un.org/sdgs/report/2023/The-Sustainable-Development-Goals-Report-2023.pdf

Brief review of progress on SDG6 is shown below.

SDG 6

The eight targets of SDG 6 include: **(1)** drinking water (target 6.1), **(2)** sanitation and hygiene (6.2), **(3)** water quality (6.3), **(4)** water-use efficiency and level of water stress (6.4), **(5)** integrated water resources management (IWRM) and transboundary water cooperation (6.5), **(6)** water-related ecosystems (6.6), **(7)** international water cooperation (6.a), and **(8)** community participation (6.b).

According to the midterm review from the SDG 6 Synthesis Report on Water and Sanitation 2023,[378] progress towards SDG 6 continues to be well below the pace needed to meet the targets by 2030:

- To meet the global target of universal access by 2030, progress needs to increase six times faster for safely managed drinking water, five times faster for

[378] based on the results of the third round of global data compilation on SDG 6 indicators in 2023 as part of the Integrated Monitoring Initiative for SDG 6

safely managed sanitation and three times faster for basic hygiene.

- A significant portion (42%) of household wastewater is not treated properly. Data gaps make it difficult to assess global trends.

- Water stress has increased globally.

- Since 2017 to 2023, the global average degree of IWRM implementation increased from 49 to 57%, but the currents rates of progress need to be doubled to achieve the global target:

(a) *at the regional level, significant efforts to accelerate IWRM implementation are needed in Central and Southern Asia, Latin America and the Caribbean, Oceania and sub-Saharan Africa since these regions have made limited progress and are lagging behind other regions;*

(b) *only **44** countries have achieved a high or very high degree of IWRM implementation. At the current rates of implementation progress, at least 107 countries will not achieve the target by 2030;*

(c) *the results show a need to accelerate transboundary cooperation: out of 153 countries that share transboundary waters, only **24** countries reported that all the rivers, lakes and aquifers they share are covered by operational arrangements for cooperation;*

(d) *Europe and North America, and sub-Saharan Africa are the most advanced SDG regions in terms of transboundary water cooperation. Progress in Latin America and the Caribbean, all Asian subregions and, more generally, for transboundary aquifers is significantly lagging behind.*

- The extent of surface water available in one fifth of the world's river basins changed significantly due to climate change and inefficient water management.

- On targets 6.a and 6.b ODA fell by 12% from 2015 to 2021, while disbursement decreased by 15% despite growing needs for financing. Although national laws and policies for community participation are increasing, their actual implementation is limited.

Progress on SDGs in the Central Asian countries

In 2023, the Central Asian region has shown mixed progress towards the SDGs.

Republic of Kazakhstan.[379] As of 2023, Kazakhstan ranked 66th out of 163 countries in the SDG Index, scoring 71.7 out of 100. The only goal achieved since the adoption of SDGs is No poverty (SDG 1). Challenges persist in SDGs related to malnutrition (SDG 2), clean energy (SDG 7), climate change (SDG 13), terrestrial ecosystems (SDG 15), peace and justice (SDG 16).[380]

For SDG 6, significant growth of IWRM implementation was recorded – from **30%** in 2017 to **51%** in 2023; the share of transboundary water basins covered by operational arrangements for cooperation reached **63.4%**. At the same time, the proportion of rivers with good water quality decreased from 72.5% in 2020 to 48.9% in 2023.

The Carbon Neutrality Strategy 2060 was officially adopted by Kazakhstan in February 2023. Kazakhstan has also joined the Global Methane Pledge at COP28, committing to reducing its GHG emissions. The updated Nationally Determined Contribution (NDC) was approved by governmental resolution.[381] The country commits to reduce GHG emissions by 25% by the end of 2030 relative to 1990 base year (SDG 7 and 13).

The mean area that is protected in freshwater sites important to biodiversity (SDG 15) increased from **8.4%** in 2000 to **20.5%** in 2023, and the mean area that is protected in terrestrial sites important to biodiversity increased from **8.9%** in 2000 to **28.5%** in 2023.

Kyrgyz Republic.[382] In the SDG Index Rank 2023 Kyrgyzstan was 48th out of 166 countries, and its SDC Index score reached **74.19**, being the highest score for Central Asia. Positive dynamics is maintained for SDG 4 (quality education), SDG 11 (sustainable cities and communities) and SDG 13 (climate action).

The percentage of population using at least basin drinking water services reached **95.37%**; the proportion of safely treated household and industrial wastewater is maintained at about **97%** since 2021 (SDG 6). In 2023, the Republic showed a moderately low (38%) degree of IWRM implementation. The share of transboundary water basins covered by operational arrangements for cooperation reached 39%.

On SDG 7, the percentage of population with access to electricity increased from **70.82%** in 2021 to **73.21%** in 2023, including **19.93%** of the population using mostly clean fuels and technology.

To preserve terrestrial ecosystems, the Republic has established a network of designated conservation

[379] https://kazakhstan.un.org/en/sdgs
[380] https://halykfinance.kz/download/files/analytics/AC_UN_report_.pdf
[381] No.313 of 19 April 2023
[382] https://sustainabledevelopment-kyrgyzstan.github.io/

areas covering **7.38%** of the country's total area. The network includes 10 state natural reserves, 13 state natural parks and 64 wildlife sanctuaries (SDG 15).

Republic of Tajikistan. In the SDG Index Rank 2023 Tajikistan was 89th out of 166 countries, scoring 68.09. Tajikistan is on the way to achieve SDG 1 (poverty eradication) and SDG 10 (reduced inequalities). Significant progress was achieved on SDG 16 (peace, justice and strong institutions) and SDG 11 (sustainable cities and communities).

Relatively moderate progress is observed towards other SDGs, including access to clean water and sanitation (SDG 6), affordable and clean energy (SDG 7) and climate action (SDG 13). For example, Tajikistan currently generates **98%** of its electricity from hydropower. The country ranks sixth in the world in terms of green energy, and will rise to the fourth position after the completion of the Rogun HPP. Tajikistan is also among the countries with almost zero contribution to greenhouse gas emissions.

The degree of IWRM implementation in Tajikistan is **54%**.

The mean percentage area of freshwater key biodiversity areas that are protected (SDG 15) increased from **27.9%** in 2000 to **30.5%** in 2023.

Turkmenistan.[383] With 67.13 score, Turkmenistan was 94th out of 166 countries in the SDG Index Rank. Turkmenistan has achieved SDG 1 (poverty eradication).

Turkmenistan maintained a consistently high level of coverage of SDG targets and indicators in strategic and policy documents (**85%**). For example, the National Climate Change Strategy and the National Action Program for Combatting Desertification aim to improve efficiency of mitigation measures (SDG 13). Turkmenistan NDC[384] provides for reducing GHG emissions by **20%** in 2030 relative to the level of emissions in 2010.

In 2023, the degree of IWRM implementation (SDG 6) was **68%**, and the proportion of transboundary river and lake basins covered by operational arrangements for water cooperation was **66.02%**. The proportion of safely treated wastewater decreased from **57.4%** in 2022 to **48.7%** in 2023.

There was a decline in the transition to sustainable forest management in 2022, which continued in 2023 (from **34.78 thousand ha** in 2021 to **3.4 thousand ha** in 2023). The proportion of land that is degraded over total land area was **17.7%** (SDG 15).

Republic of Uzbekistan.[385] With a score of 71.1, Uzbekistan has secured the 69th rank out of 166 countries in the SDG Index Rank 2023, thus climbing eight positions from its preceding year's rank.

According to the World Resources Institute, the country was ranked 25th out of 164 in the ranking of countries suffering from water stress. The critical level of pressure on water resources in Uzbekistan results from the use of 169% of water reserves. Drinking water supply in Uzbekistan is provided through increased access of population to centralized drinking water supply. The share of population provided with safe water services (SDG 6) increased to **99.8%.** The share of transboundary water basins covered by operational arrangements for cooperation is **70%** and the degree of IWRM implementation is **64%.**

According to UNDP, the alignment of global Sustainable Development Goals with national strategic development planning in Uzbekistan is currently at 79%. The least integration is found to be in SDG 13 – **60%.**

In line with the "Concept for the Development of the Forestry System of the Republic of Uzbekistan until 2030" expansive measures were taken to establish protective forest plantations over the desiccated bed of the Aral Sea (SDG 15). Between 2019 and 2023 alone, initiatives spanned across more than 1.7 million hectares. The forest area out of total land area of Uzbekistan increased from **8.6%** (2019) to **10.6%** (2023).

Uzbekistan's heavy reliance on natural gas continues to pose energy security risks, exacerbated by depleting gas production and increasing net imports (SDG 7).

12.3. Earth Overshoot Day 2023

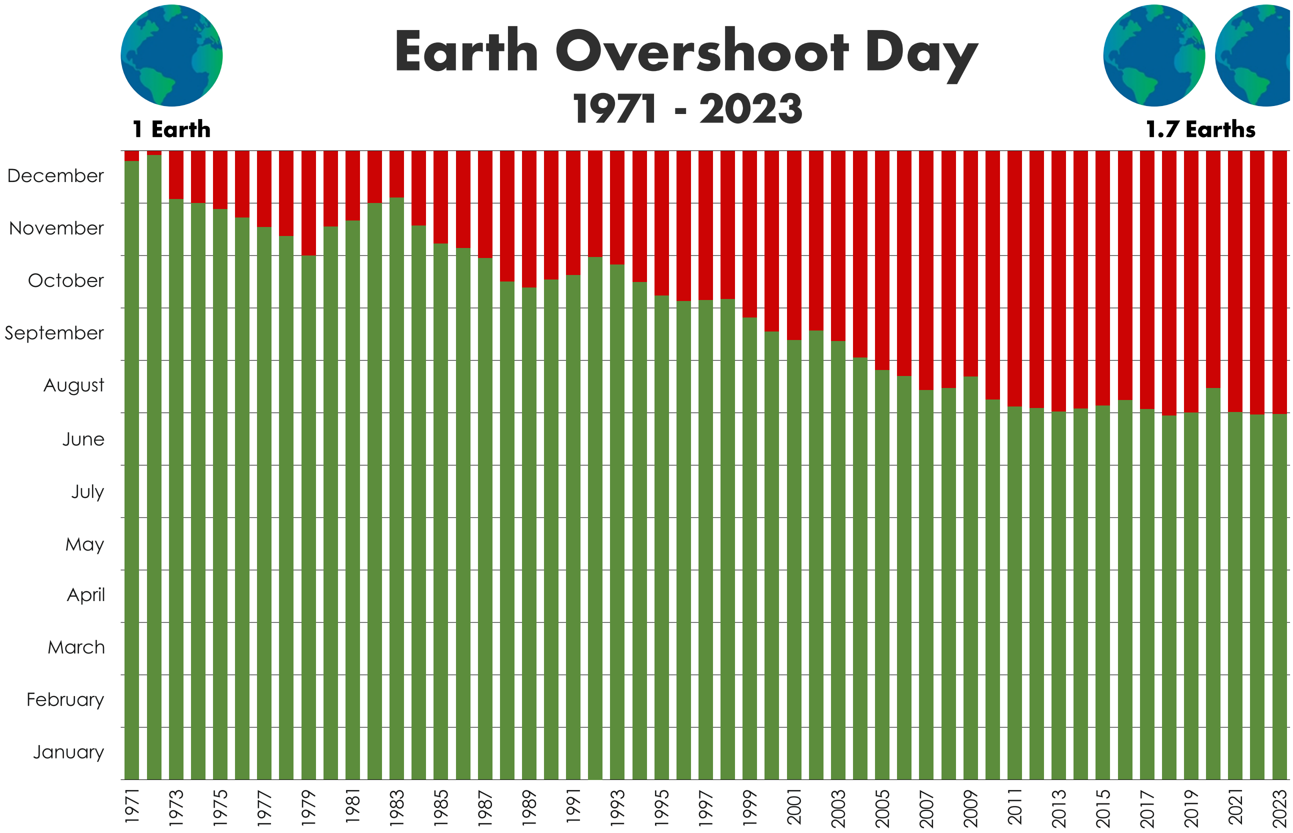
Each year, Earth Overshoot Day marks the date when we have used all the biological resources that the Earth can renew during the entire year. In 2023, it falls on **2 August**. This means that humanity currently uses 75% more than what the planet's eco-systems can regenerate. From this day until the end of the year, humanity operates on ecological deficit spending.

A Country Overshoot Day reflects the ecological footprint of a country by comparing the population's demand and the nation's biocapacity.

On a planetary scale, minimizing ecological footprint necessitates the conservation and restoration of ecosystems. If we prevent food loss and food waste, prefer plant based foods, and choose foods that are

[383] https://sdg.stat.gov.tm/ru/
[384] submitted to UNFCCC in May 2022
[385] https://nsdg.stat.uz/

Earth Overshoot Day
1971 - 2023

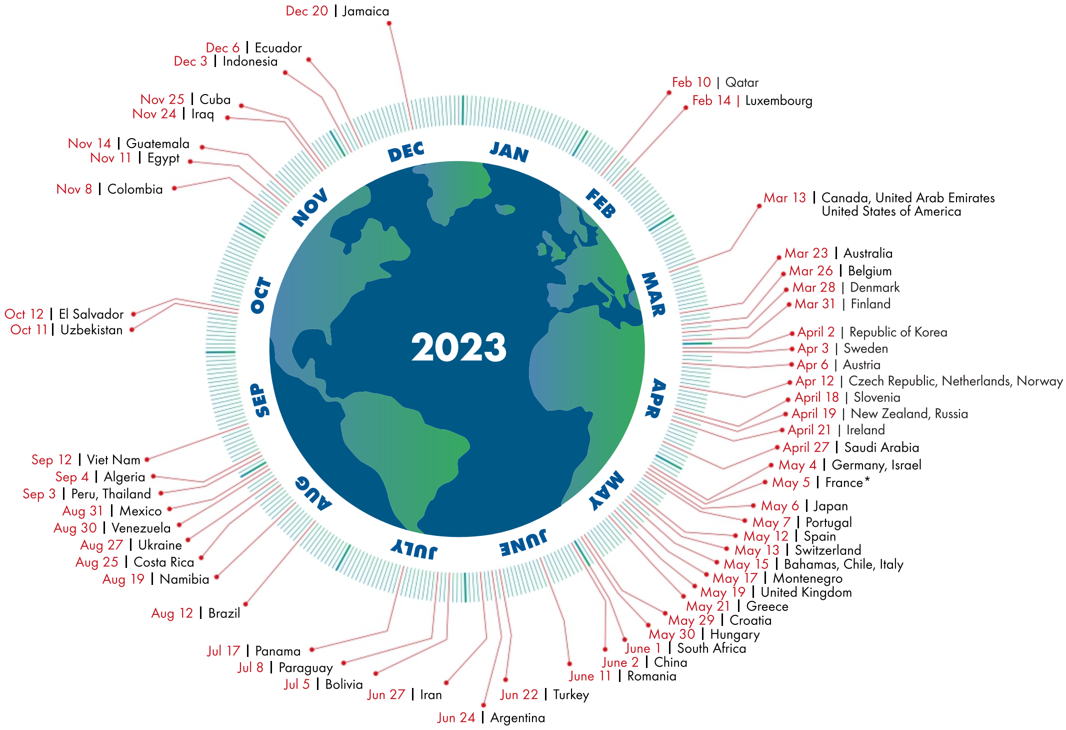


EARTH OVERSHOOT DAY   FODAFO FOOTPRINT DATA FOUNDATION   Global Footprint Network Advancing the Science of Sustainability

Source: National Footprint and Biocapacity Accounts 2023 Edition
data.footprintnetwork.org

Country Overshoot Days 2023

When would Earth Overshoot Day land if the world's population lived like...



For a full list of countries, visit overshootday.org/country-overshoot-days.
*French Overshoot Day based on nowcasted data. See overshootday.org/france.

EARTH OVERSHOOT DAY

Source: National Footprint and Biocapacity Accounts, 2022 Edition
data.footprintnetwork.org

Global Footprint Network Advancing the Science of Sustainability grown with agroecological and regenerative practices, we could move Earth Overshoot Day **32 days**. If we reduced global meat consumption by 50% and replaced these calories through a vegetarian diet, we would move Overshoot Day **17 days** (including 10 days from reduction of methane emissions) as half of Earth's biocapacity is used to feed us. Reforesting 350 million hectares of forest would move the date of Overshoot Day by 8 days.

If we reduce our Footprint from driving by 50% around the world and assume one-third of car miles are replaced by public transportation and the rest by biking and walking, Earth Overshoot Day would move back 13 days.

Reducing the carbon component of humanity's Ecological Footprint by 50% would move Earth Overshoot Day by 93 days, or more than three months. Existing off-the-shelf, commercial energy-efficiency technologies for buildings, industrial processes, and electricity production could move Overshoot Day at least 21 days, without any loss in productivity or comfort.

The United Nations projects that between 7.3 to 15.6 billion people will be living on Earth by 2100. Avoiding the population conversation does nothing to address one of the most significant contributors to humanity's increasing demand on the planet. If every other family had one less child and parenthood was postponed by two years, by 2050 we would move Overshoot Day 49 days.

12.4. Artificial intelligence and water resources management

Prepared by M.S. Valieva, D.R. Ziganshina (SIC ICWC)

The year 2023 will be remembered as a watershed moment in our collective understanding of artificial intelligence (AI). The launch of ChatGPT[386] late last year catalyzed widespread exploration of AI's capabilities, its potential impact (both beneficial and detrimental), and its practical applications in daily life. This phenomenon was reflected in numerous rankings that identified AI development as a defining event of the year, alongside significant geopolitical shifts.[387] Major consulting firms and leading universities[388] conducted extensive research on AI's economic and societal implications.[389] International news outlets extensively covered the technology, highlighting both its promise and its perils.

This review will delve into the specific applications of AI technologies within the critical domain of water resource management, while also examining the potential risks associated with their implementation.

Artificial Intelligence: Key Concepts

Artificial Intelligence (AI) refers to the ability of computer systems to perform creative functions that have traditionally been considered the prerogative of humans. Specific applications of AI include various expert systems, information processing in multiple languages, speech recognition, and systems used for financial trading. Two important concepts that are often mentioned in the context of AI are machine learning and computer vision.

Machine learning is an AI field focused on creating systems that learn and evolve based on the data they receive[390]. One of the best-known machine learning methods is the Artificial Neural Network (ANN) that works by mimicking biological neural networks that exist in a human brain. ANNs learn from training data[391] presented to them in order to capture the functional relationships among the data, even if the underlying relationships are not known or the physical meaning is difficult to explain. This enables the ANNs to discover patterns in data that are often unknown, even to the best experts in the field[392].

Computer Vision is an AI field related to image and video analysis; it includes a set of methods that empower a computer with the ability to interpret and understand digital images and videos. Examples of computer vision applications include systems for facial recognition, medical diagnostics and driverless cars[393].

[386] developed by OpenAI

[387] Council on Foreign Relations (2023), *Ten most significant world events of 2023*.
URL: https://www.cfr.org/blog/ten-most-significant-world-events-2023

[388] Stanford Human-Centered AI Institute (2023), *13 biggest AI stories of 2023*.
URL: https://hai.stanford.edu/news/13-biggest-ai-stories-2023

[389] Hatzius J.,Briggs, J., Kodnani, A., Pierdomenico G. (2023), *The potentially large effects of artificial intelligence on economic growth*,
URL: https://www.key4biz.it/wp-content/uploads/2023/03/Global-Economics-Analyst_-The-Potentially-Large-Effects-of-Artificial-Intelligence-on-Economic-Growth-Briggs_Kodnani.pdf

[390] Oracle. (n.d.). *Что такое машинное обучение? (What is machine learning?)*
URL: https://www.oracle.com/cis/artificial-intelligence/machine-learning/what-is-machine-learning/

[391] Training Data is used in machine learning in conjunction with Validation Data and Testing Data. Based on them, the model learns to process information

[392] International Water Association (2020), *Digital Water. Artificial Intelligence: Solutions for the Water Sector*.
URL: https://iwa-network.org/wp-content/uploads/2020/08/IWA_2020_Artificial_Intelligence_SCREEN.pdf

[393] International Water Association (2020), *Digital Water. Artificial Intelligence: Solutions for the Water Sector*.
URL: https://iwa-network.org/wp-content/uploads/2020/08/IWA_2020_Artificial_Intelligence_SCREEN.pdf

A short digression

The term "artificial intelligence" (AI) was coined in 1956 at a workshop at Dartmouth College, USA. This workshop focused on developing methods for solving logical, rather than purely computational, problems. Notably, the English term "intelligence" signifies "the ability to reason intelligently," distinct from "intellect." This subtle nuance is often lost in translation, where "artificial intelligence" can carry a slightly anthropomorphic, almost fantastical connotation.

Shortly after its establishment as a distinct scientific field, AI research bifurcated into two major branches: neurocybernetics and "black box cybernetics." These branches have evolved largely independently, exhibiting significant differences in both methodology and technological approaches.

(Quoted by: T. Gavrilova, V. Khoroshevsky. Knowledge bases of intelligent systems. St. Petersburg: Peter, 2000 - 384 p.)

ChatGPT (short for Generative Pre-trained Transformer) is a chatbot with generative artificial intelligence that can operate in a dialog mode and handle queries in multiple languages. A key feature is its ability to generate code in various programming languages upon request[394].

Internet of Things (IoT) is the concept of a data transmission network between physical objects equipped with built – in tools and technologies to interact with each other or with the external environment.

General trends in AI development in 2023

The latest annual McKinsey Global Survey on the current state of AI confirms the explosive growth of generative AI (gen AI) tools. Less than a year after many of these tools debuted, one-third of respondents reported that their organizations regularly use GenAI in at least one business function. Amid recent advances, AI has risen from a topic relegated to tech employees to a focus of company leaders: nearly a quarter of them report personal use of AI tools for work. Furthermore, 40% of respondents say their organizations will generally increase investments in AI[395].

According to the BBC[396], many employees use AI to solve administrative tasks, such as writing simple texts and generating ideas, which helps save time and frees up workers to focus on creative and more complex tasks[397].

According to forecasts, AI has the potential to both create millions of new jobs and displace many existing ones. The World Economic Forum's Future of Jobs Report 2023 highlights that AI and machine learning specialists, data analysts and scientists, and digital transformation specialists are among the fastest-growing roles. However, AI cannot replace all professions, particularly those requiring common sense, creativity, physical dexterity, and emotional intelligence[398].

Fastest growing vs. fastest declining jobs

WORLD ECONOMIC FORUM

Top-10 fastest growing jobs

1.	AI and Machine Learning Specialists
2.	Sustainability Specialists
3.	Business Intelligence Analysts
4.	Information Security Analysts
5.	Fintech Engineers
6.	Data Analysts and Scientists
7.	Robotics Engineers
8.	Big Data Specialists
9.	Agricultural Equipment Operators
10.	Digital Transformation Specialists

Top-10 fastest declining jobs

1.	Bank Tellers and Related Clerks
2.	Postal Service Clerks
3.	Cashiers and ticket Clerks
4.	Data Entry Clerks
5.	Administrative and Executive Secretaries
6.	Material-Recording and Stock-Keeping Clerks
7.	Accounting, Bookkeeping and Payroll Clerks
8.	Legislators and Officials
9.	Statistical, Finance and Insurance Clerks
10.	Door-To-Door Sales Workers, News and Street Vendors, and Related Workers

Note
The jobs which survey respondents expect to grow most quickly from 2023 to 2027 as a fraction of present employment figures

Source
World Economic Forum, Future of Jobs Report 2023

[394] Wikipedia contributors (2024), *ChatGPT*, URL: https://ru.wikipedia.org/wiki/ChatGPT

[395] McKinsey & Company (2023), *The state of AI in 2023: Generative AI's breakout year.* URL: https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai-in-2023-generative-ais-breakout-year#/

[396] British Broadcasting Corporation (BBC)

[397] BBC (2023), *Panic and possibility: What workers learned about AI in 2023.* URL: https://www.bbc.com/worklife/article/20231219-panic-and-possibility-what-workers-learned-about-ai-in-2023

[398] World Economic Forum (2023), *Everything you need to know about AI in 2023: the 6 must-read blogs.* URL: https://www.weforum.org/agenda/2023/11/ai-2023-governance-summit/

In everyday life, AI has become an integral part, assisting through virtual assistants (Siri, Alexa, Alice), providing recommendations and information on search and entertainment platforms (Netflix, Spotify, Yandex), and more. In healthcare, AI is used for accurate diagnosis and personalized treatment. In digital advertising and financial security, AI enhances ad targeting and fraud detection. In the automotive industry, AI supports the development of autonomous vehicles, potentially increasing safety and efficiency in transportation. With the correct design of requests, AI is also effective in creating educational programs, selecting teaching models, and preparing instructional materials.

The use of AI in the water sector

The potential applications of AI in the water sector are immense. Below are some of the most compelling aspects of its use in data monitoring and analysis:

- ***Water Demand Management.*** AI is capable of uncovering hidden trends in large datasets, enabling utilities to forecast demand, optimize water distribution throughout the day, reduce waste, and meet needs more effectively. Machine learning algorithms can analyze real-time data to adjust water flow and pressure, maintaining a steady supply and minimizing losses during maintenance. AI models trained to consider weather conditions, seasonality, and other factors can identify large-scale issues in water usage and assist in decision-making related to infrastructure, investments, and resources. For instance, Singapore uses intelligent water management systems that use AI to forecast water demand and optimize supply.

- ***Weather and Climate Forecasting.*** AI-based water management models, incorporating data from the Internet of Things (IoT), can analyze disparate datasets to assess climate risks and develop adaptive water supply strategies. AI is used to create predictive models that forecast water resource availability based on climate change scenarios. These models can integrate a wide range of data, including historical weather patterns, current climate trends, and future climate projections. By analyzing this data, AI can provide valuable insights into the impact of climate change on future water availability. A study by Stanford University demonstrated AI's potential in forecasting groundwater recharge, with the AI model achieving high accuracy in predicting groundwater replenishment rates[399].

- Researchers from Nvidia and Google have embarked on developing large AI models, known as foundation models, for weather forecasting. These models are capable of providing more accurate forecasts compared to existing numerical models and have lower computation costs[400]. Some of these models can predict weather conditions beyond seven days, opening new avenues for scientists[401]. Methods for assessing precipitation intensity using video streams from smartphones or surveillance cameras, as well as unconventional IoT data sources, are advancing. Technological advances in image processing and computer vision enable extraction of diverse features, including identification of rain streaks enabling estimation of the instantaneous rainfall intensity (Allamano et al, 2015). Recent AI and machine learning approaches rely on the use of autoencoders, deep learning[402] and convolutional neural networks[403] to address the problems. Companies such as WaterView (Italy), Hydroinformatics Institute (Singapore), as well as universities (Southern University of Science and Technology China, Shenzhen) have proposed and implemented practical approaches to weather hazards in energy, automotive and smart cities application domains (Jiant et al, 2019)[404].

- ***Forecasting and Mitigating Potential Water-Related Risks.*** Flooding poses a persistent threat in many urban areas and communities. AI can be used to analyze weather and water level data, as well as to predict the likelihood of flooding. This capability enables local authorities to implement preventive measures and evacuate individuals from high-risk areas. IBM[405] employs AI to develop predictive analytics[406] tools and optimize water resource management. Their solutions assist cities and industrial enterprises in effectively managing water resources.

The Serbian company Vodena is developing an innovative solution, VodostAI, to combat flooding in the Western Balkans, where damages amounted to €300 million in 2023 and over one million people were affected. The VodostAI platform employs AI and the Internet of Things (IoT) for continuous monitoring and updating of models based on new data. Vodena automates data collection using intelligent sensors and machine learning algorithms, enabling accu-

[399] David Cain (2023), *Water Management enhanced by AI*. URL: https://www.linkedin.com/pulse/making-splash-how-ai-diving-water management-david-cain/

[400] Computation cost refers to the total amount of time and resources required for processing and transferring data in a computing application

[401] Национальное информационное агентство «Экология» (2024), *Искусственный интеллект революционизирует прогнозирование погоды (Artificial intelligence revolutionizes weather forecasting)*. URL: https://nia.eco/2024/07/10/86258/

[402] Deep learning is a type of machine learning using multi – layered neural networks that self-learn on a large dataset

[403] Convolutional Neural Networks (CNN) is a class of machine learning algorithms. With their help, it is possible to achieve impressive results in the field of pattern recognition, image classification, as well as video data processing and analysis

[404] International Water Association (2020), *Digital Water. Artificial Intelligence: Solutions for the Water Sector*. URL: https://iwa-network.org/wp-content/uploads/2020/08/IWA_2020_Artificial_Intelligence_SCREEN.pdf

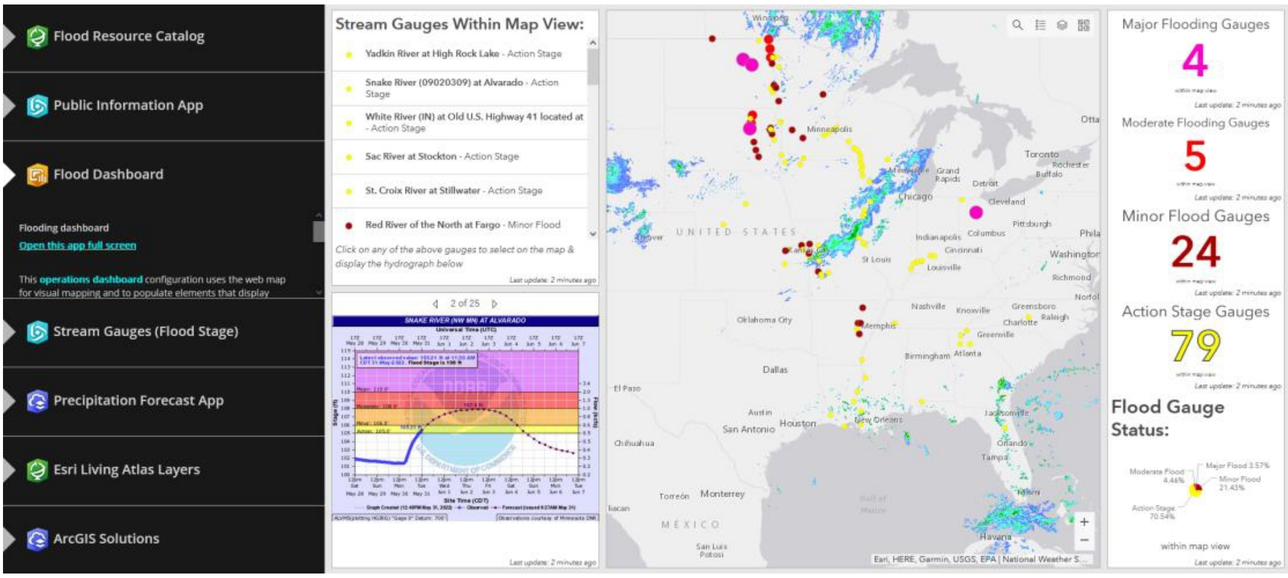
[405] International Business Machines is an American company headquartered in Armonk. One of the world's largest manufacturers and suppliers of hardware and software, as well as IT services and consulting services

[406] Predictive analytics is one of the areas of data analysis that focuses on predicting future events based on retrospective data

rate water level forecasting and timely notifications[407].

In 2018, Google launched an AI-based flood forecasting system in India, a country frequently affected by severe flooding. The system employs a combination of machine learning, hydrological models, and the most up-to-date weather data to predict areas at risk of flooding. According to a report by The Times of India, the system successfully provides timely and accurate flood threat alerts, allowing local communities to take necessary precautions and potentially saving countless lives[408].

Interactive web map



Source: Sakti Prajna Mahardhika and Okkie Putriani (2023), IOP Conf. Ser.: Earth Environ. Sci. 1195 012056.
URL: https://iopscience.iop.org/article/10.1088/1755-1315/1195/1/012056/pdf

- ***Optimization of Water Consumption.*** This approach is based on the concept of automated data analysis. The platform developed by Plutoshift, which employs AI, collects data from various sources and then processes it using machine learning algorithms to provide real-time insights for optimizing water use. The platform can identify patterns and trends that are difficult for humans to discern and forecast future water consumption based on historical data and current conditions. By optimizing water use, businesses can significantly reduce their operational costs. For instance, a beverage company utilizing Plutoshift's platform was able to save $140,000 annually[409].

- ***Optimization of Irrigation Systems.*** AI-driven irrigation systems optimize water resource use by utilizing data on weather conditions, soil moisture levels, and crop requirements. These systems ensure that agricultural crops receive the precise amount of water needed at the appropriate times, reducing waste and improving yield. An example of such technology is the AI-based irrigation systems from Netafim. Economic benefits of intelligent irrigation systems include substantial cost savings through reduced water and energy consumption. Although the initial investment in these systems may be significant, they typically pay off within one to three years through water savings, reduced labor costs, and increased yields. Additionally, improvements in soil fertility and environmental sustainability provide long-term advantages[410].

- ***Enhancing Water Supply Efficiency.*** As highlighted in the Water Technology Trends 2023, AI models can be employed to optimize water supply systems, minimize costs, reduce water losses, and improve the energy efficiency of infrastructure. This can contribute to lowering operational and maintenance expenses while enhancing access to clean water.

The AI-based WaterScope solution detects leaks in municipal water supply systems and provides real-

[407] Aquatech Trade (2024), *Essential Guide: How AI is used in the water sector.*
URL: https://www.aquatechtrade.com/news/digital solutions/essential-guide-ai-and-water#:~:text=just%20a%20few%3A-%22AI%20helps%20us%20to%20make%20faster%20decisions%20using%20the%20full,networks%2C%20facilitating%20the%20detection%20of

[408] David Cain (2023), *Water Management enhanced by AI.*
URL: https://www.linkedin.com/pulse/making-splash-how-ai-diving-water-management-david-cain/

[409] David Cain (2023), *Water Management enhanced by AI.*
URL: https://www.linkedin.com/pulse/making-splash-how-ai-diving-water-management-david-cain/

[410] Nichols, J. (2024), *Economic Benefits of IoT-Driven Smart Irrigation Systems. Smart Water Magazine.*
URL: https://smartwatermagazine.com/blogs/justin-nichols/economic-benefits-iot-driven-smart-irrigation-systems

time alerts to prevent water loss. Siemens utilizes AI and the Internet of Things to deliver digital solutions that enhance water resource management and operational efficiency. The company Fracta has leveraged AI capabilities to refine methods for detecting and addressing losses in water infrastructure. Fracta employs machine learning to predict the likelihood of pipe failures in water supply systems. The AI system processes extensive datasets, including pipe material, age, diameter, and historical leak data. Machine learning algorithms are then applied to these data to predict where leaks are most likely to occur. This leak prediction method has been practically implemented with excellent results. For instance, Fracta's AI-based leak detection system was adopted by the Murfreesboro Water Resources Department in Tennessee, USA, and identified potential leaks with up to 69% accuracy, significantly surpassing industry standards. By forecasting likely leak locations, the system enables proactive maintenance, thereby preventing costly and damaging pipeline failures[411].

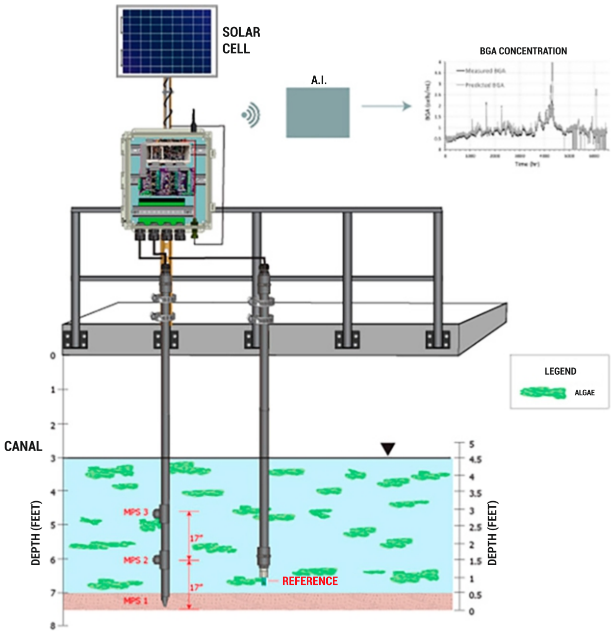
- ***Detection of Crop Growth Anomalies.*** This process involves identifying irrigation issues and implementing timely corrective actions. When planning crops, AI analyzes data related to crop selection parameters, enabling optimal crop choices and the development of predictive models for future water supply needs. This supports the creation of resilient and sustainable agricultural systems that are adaptable to changing water availability conditions.

- ***Water Quality Monitoring.*** The Netherlands, renowned for its innovative water management strategies, is at the forefront of integrating AI into water quality monitoring. A notable project in this regard is the "AI for Water Quality" (AI4WQ) initiative, undertaken collaboratively by water authorities, research institutions, and technology companies. The AI4WQ project utilizes AI algorithms to process vast datasets collected from various sensors installed in water bodies throughout the Netherlands. These sensors measure real-time data on temperature, pH, turbidity, and concentrations of various chemical and biological substances, identifying patterns and trends that may indicate changes in water quality[412].

The U.S. Environmental Protection Agency (EPA) also employs AI for real-time water quality monitoring and the detection of pollutants. Hitachi leverages AI to provide advanced water resource management solutions, including predictive maintenance and optimization of water distribution networks.

Peter Ma from Intel has developed a prototype system that uses AI methods for detecting bacteria in water. This system features a digital microscope connected to a portable computer running Ubuntu

Real-time monitoring and forecasting of water quality



Source: Hesam Kamyab, Tayebeh Khademi, Shreeshivadasan Chelliapan, Morteza Saberi Kamarposhti, Shahabaldin Rezania, Mohammad Yusuf, Mohammad Farajnezhad, Mohamed Abbasi, Byong Hun Jeon, Yongtae Ahn (2023). The latest innovative avenues for the utilization of artificial Intelligence and big data analytics in water resource management. Results in Engineering 20 (2023) 101566

and an Intel Movidius neural computer, enabling autonomous analysis and real-time mapping of contamination zones.

The platform, based on Intel Xeon processors, is designed for deep learning and computational tasks. Peter utilized Intel AI DevCloud to train the AI model and the Intel Movidius Neural Compute Stick for real-time water testing.

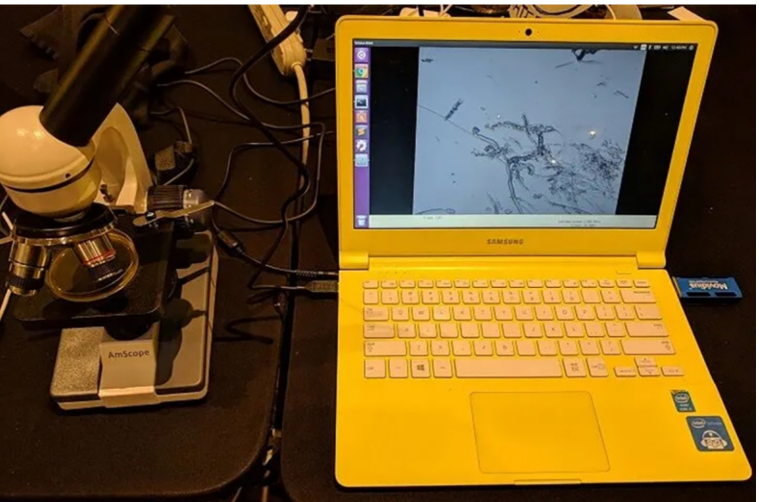
The entire testing system is composed of readily available components, such as a digital microscope and inexpensive computing devices, with a total cost not exceeding $500. The underlying convolutional neural network enables the identification of current bacteria, such as E. coli and Vibrio cholerae, with the capability to extend the detection range[413].

AI also enables the detection of unregistered carcinogenic contaminants globally. Chinese scientists have developed a new platform for the detection and precise identification of unknown PFAS (per- and polyfluoroalkyl substances) in the environment. The platform employs an advanced molecular screening tool integrated with machine learning, allowing for

[411] David Cain (2023), *Water Management enhanced by AI.*
URL: https://www.linkedin.com/pulse/making-splash-how-ai-diving-water management-david-cain/

[412] David Cain (2023), *Water Management enhanced by AI.*
URL: https://www.linkedin.com/pulse/making-splash-how-ai-diving-water management-david-cain/

[413] Datafloq (2018), *AI-Driven Test System Detects Bacteria in Water.*
URL: https://datafloq.com/read/ai-driven-test-system-detects-bacteria-in water/



Basic testing system
Datafloq (2018), AI-Driven Test System Detects Bacteria in Water

the identification of 733 PFAS in wastewater, of which 17 groups were previously unknown. Additionally, 126 PFAS were detected in samples from 20 countries, including 37 new and 81 previously unrecognized substances. The platform achieves an accuracy of 58.3% with a low false positive rate of 0.7%, significantly surpassing other methods. This advancement provides opportunities for better risk management and enhances the study of synthetic chemicals' impact on health and the environment[414].

- ***Air Quality Monitoring.*** AI can be utilized to monitor air quality at water treatment facilities. This capability can detect and prevent air pollution that may adversely affect water quality.

In addition to fundamental research and development, it is crucial to focus on the practical application of innovations, including prototype development, localization, and user engagement. In this context, the advancement of AI technologies contributes to addressing the following challenges[415]:

- ***Organizing Unstructured Earth Data and Localizing Models.*** Earth sciences rely on vast amounts of unstructured and disorganized data, with over 100 terabytes of satellite imagery collected daily. Recent research and developments illustrate AI's ability to optimize these data. For example, Google Earth Engine, a leading platform for Earth observation, integrates various satellite images and geospatial data with analytical capabilities. AI also advances Earth sciences by adapting global models to local conditions through transfer learning[416]. This method leverages previously studied information about specific areas to address tasks such as predicting forest fires in particular locations. This is especially crucial in data-sparse regions, as it helps bridge information gaps and effectively utilize extensive observational data.

- ***Simplifying Model Understanding.*** Generative AI, based on large language models (LLM), facilitates interactive engagement with data users and simplifies the understanding of complex processes. By providing a GPT-like interface, it enables users of all skill levels to interact with climate and hydrological data tailored to their needs.

- ***Accelerating the Prototyping Stage in Technology Development.*** AI can shorten the deep tech cycle, particularly in prototyping, speeding up the introduction of essential technologies. In materials science, AI accelerates discovery and design, crucial for climate mitigation (such as improving lithium-ion batteries and solar cells) and adaptation (developing fire-resistant materials). Traditional methods, which calculate material properties from scratch, consume significant time, costs and computational resources. Up to one-third of global supercomputing power is used for materials science. AI now predicts new material properties without exhaustive initial calculations. It does this by learning relationships between atomic structures and their properties, and suggesting optimal configurations. While this is a nascent space with limitations (e.g. documented "hallucinations"[417] in discovery processes), there is significant potential for innovation. For example, GenAI is tackling the inverse design problem, which starts with a desired property (e.g. resilience to extreme weather) and reverse-engineers its design[418].

Risks of AI Deployment

Currently, it is challenging to definitively assess the consequences of using AI, as people tend to overestimate the short-term impacts of new technologies while significantly underestimating their long-term effects. Overall, experts highlight the following risks associated with the deployment of AI, including in the water sector:

- ***Data Volume.*** Effective AI models require large volumes of high-quality data, which may not always be available, particularly in developing countries.

- ***Limitation.*** AI models are trained on limited data, which can lead to mediocre or insufficient re-

[414] Хайтек+ (2024), *Китайский ИИ обнаружил незарегистрированное канцерогенное загрязнение по всему миру (Chinese AI has discovered unregistered carcinogenic pollution around the world)*.
URL: https://hightech.plus/2024/05/28/kitaiskii-ii--obnaruzhil nezaregistrirovannoe-kancerogennoe-zagryaznenie-po-vsemu-miru

[415] World Economic Forum (2024), Post breakthrough: *How AI can lift climate research out of the lab and into the real world*.
URL: https://www.weforum.org/agenda/2024/05/ai-lift-climate-research-out-lab-and-real-world/

[416] Transfer learning (TL) is a machine learning method in which a model pre–trained to perform one task is configured to perform a new one related to the previous one

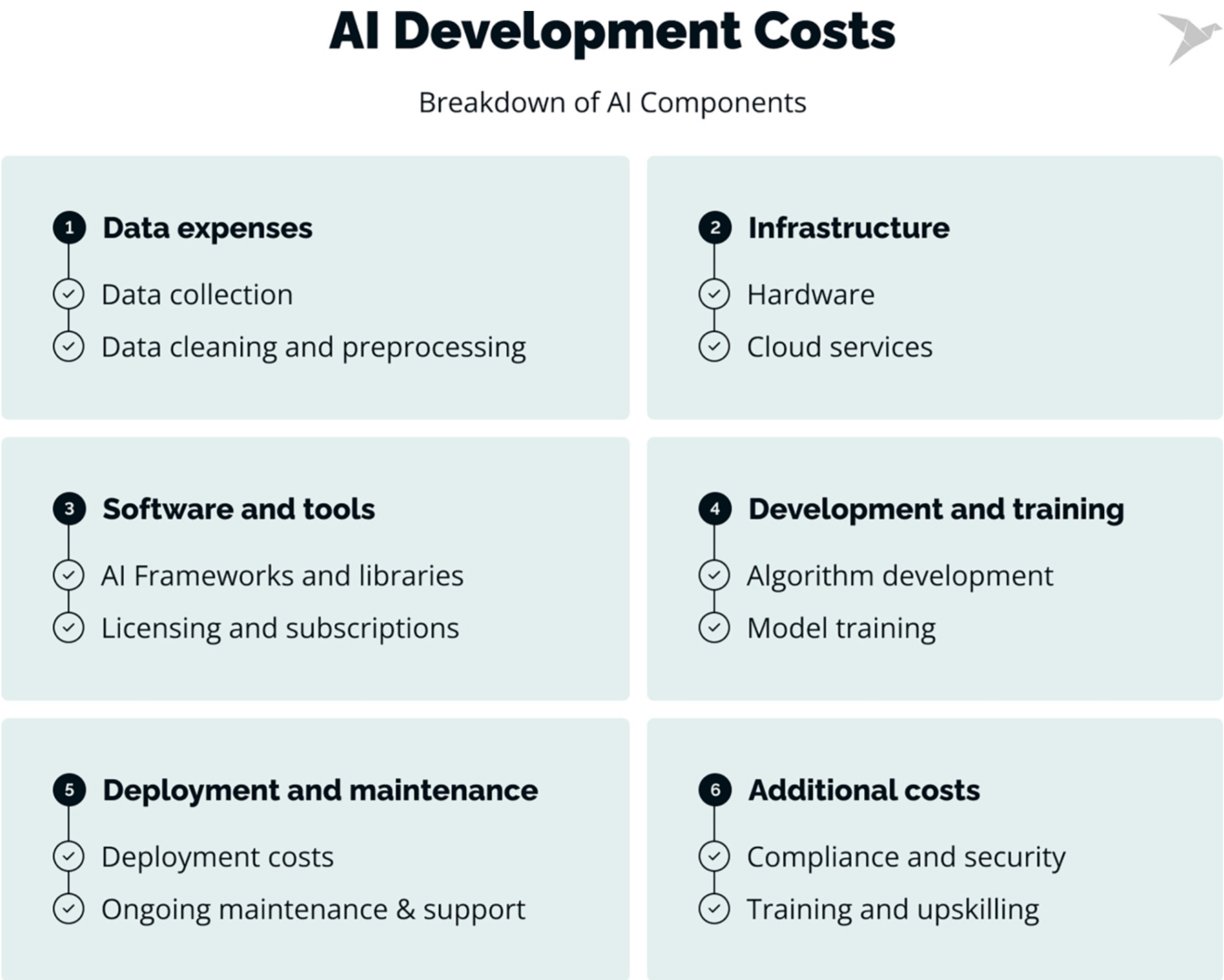
[417] In artificial intelligence, a hallucination or artificial hallucination is a confident reaction of an AI that is not supported by its training data, or fictional responses that are unrelated to reality

[418] Reverse engineering is a method of disassembling an object that helps to understand how a previously created device, process, system, or piece of software is designed

sults. This limitation may hinder innovation and development, as excessive reliance on AI without critical analysis can slow progress[419]. The ease of adopting new technologies may distract from addressing the core needs of clients and employees. It is crucial to critically evaluate AI outcomes and avoid a "set and forget" approach, which can result in a loss of expertise and critical thinking[420]. AI-generated forecasts are not infallible and should be used in conjunction with other forms of analysis and expert evaluations.

- ***Responsibility.*** Daniel Kiley from HWL Ebsworth Lawyers emphasizes the importance of maintaining accountability when using AI. Organizations must ensure the proper functionality of AI tools and take responsibility for their outcomes. The use of AI should be justified, and it is crucial to avoid shifting blame onto the tool if issues arise.

- ***Development costs***[421]. The costs associated with developing AI software can vary widely depending on numerous factors. Key factors include data costs, project complexity, infrastructure, development, deployment, regulatory compliance, and ongoing maintenance. On average, the costs for AI software development range from $50,000 to $500,000 for small to medium-sized projects and from $500,000 to $5 million for large-scale projects. While these costs can be substantial, the potential benefits of implementing AI – such as increased efficiency, reduced expenses, improved customer service, innovation, and optimized data use – often justify the investment.



Source: TechMagic (2024), AI Development Cost: Analyzing Expenses and Returns

[419] Australian Water Association (2024), *Addressing the Risks of AI in the Water Sector*.
URL: https://www.awa.asn.au/resources/latest-news/addressing-the-risks-of-ai-in-the-water-sector

[420] Australian Water Association (2024), *Addressing the Risks of AI in the Water Sector*.
URL: https://www.awa.asn.au/resources/latest-news/addressing-the-risks-of-ai-in-the-water-sector

[421] TechMagic (2024), *AI Development Cost: Analyzing Expenses and Returns*.
URL: https://www.techmagic.co/blog/ai-development-cost/#:~:text=The%20primary%20factors%20include%20data,5%2C000%2C000%20for%20large%2Dscale%20projects

■ ***High Power Consumption.*** The International Energy Agency (IEA) anticipates that the advancement of AI technologies will double the demand for electricity[422]. Data centers, numbering over 8,000 globally (with 16% located in Europe), consume substantial amounts of energy for both server operations and cooling. According to 2023 estimates by the IEA, data centers account for 1-1.5% of global electricity consumption. Their CO_2 emissions are approximately 1% of the global total, comparable to the aviation sector[423]. From 2024 to 2026, electricity consumption could potentially double, reaching the total electricity consumption level of Japan. In 2023, the share of electricity used by data centers increased to 20%, up from 18% in 2015. Queries to AI chatbots may consume up to ten times more energy than traditional Google searches, while generative AI systems can use up to 33 times more energy than conventional software. This rising energy consumption contributes to increased CO_2 emissions, as it is predominantly powered by fossil fuels.

■ ***Water Consumption.*** Data centers use a significant amount of water for cooling purposes. For instance, in the United States in 2021, approximately 7,100 liters of water were used per megawatt-hour of energy. Google's data centers alone consumed 12.7 billion liters of fresh water. This issue becomes particularly critical in water-scarce regions, especially in the context of global warming and extreme temperatures[424].

■ The use of AI also raises ***ethical and privacy*** issues related to data collection and usage, necessitating transparency and accountability. Ensuring that data practices are ethical and that privacy is protected is crucial in the deployment of AI technologies[425].

Legal Regulation of AI

The rapid development of AI technologies and the associated risks necessitate appropriate legal regulation. Many countries are in the process of establishing legal frameworks for AI implementation, but a well-established and cohesive structure is not yet in place. The European Union and China are currently leading efforts in this area.

On December 8, 2023, negotiators from the European Parliament and the Council reached a preliminary agreement on the AI Act, aimed at ensuring protection against high-risk AI applications for fundamental human rights, democracy, the rule of law, and environmental sustainability, while also promoting innovation. Specifically, the agreement includes provisions on the overarching objectives of AI; restrictions on the use of biometric identification systems by law enforcement; bans on social scoring and using AI to manipulate or exploit user vulnerabilities; the right for consumers to file complaints and receive substantive explanations; and fines ranging from €35 million (or 7% of global turnover) to €7.5 million (or 1.5% of global turnover)[426]. The agreed text now needs to be officially adopted by the Parliament and the Council. The proposed legislation has sparked mixed reactions: an open letter signed by over 150 European business leaders (from Renault to Heineken) highlights concerns that the law may negatively impact businesses and threaten regional competitiveness, while failing to address the very issues it was designed to resolve[427].

In China, specific regulatory measures concerning AI have already been implemented, but these address a narrow range of issues. A comprehensive law establishing general rules for the AI industry is still lacking. In August 2023, a preliminary draft law was prepared by a group of researchers from the Chinese Academy of Social Sciences and published for discussion as the Model Law on Artificial Intelligence, Version 1.0 (Expert Draft Proposal). Notable features of the Chinese approach include its iterative nature, allowing for adjustments with each new step, and its sector-specific focus[428].

In March 2024, the United Nations General Assembly adopted a resolution titled **"Seizing the opportunities of safe, secure, and trustworthy artificial intelligence systems for sustainable development"**.[429] Although non-binding, this resolution represents the first UN-level document aimed to establish a framework for the development and regulation of AI technologies globally. The document begins by reaffirming commitment to international law, particularly the UN Charter and the Universal Declaration of Human Rights. The reference to human rights is particularly pertinent regarding the ethical and secure use of

[422] Overclockers.ru. (2024), *МЭА ожидает увеличения спроса на электроэнергию в два раза на фоне развития ИИ-технологи (The IEA expects electricity demand to double due to the development of AI technology)*.
URL: https://overclockers.ru/blog/Vizir47/show/134982/MEA-schitaet-chto-kriptovaljuty-i-II-sozdajut-ser-eznye-energeticheskie-problemy

[423] Национальное информационное агентство «Экология» (2024), *Энергетические аппетиты ИИ: новая угроза для экологии?(Energy appetites of AI: a new threat to the environment?)*. URL: https://nia.eco/2024/07/09/86104/

[424] Национальное информационное агентство «Экология» (2024), *Энергетические аппетиты ИИ: новая угроза для экологии?(Energy appetites of AI: a new threat to the environment?)*. URL: https://nia.eco/2024/07/09/86104/

[425] TGI (2024), *AI's Role in Improving Water Resource Management*.
URL: https://www.tabsgi.com/ais-role-in-improving-water-resource-management/

[426] European Parliament (2023), *Artificial Intelligence Act: Deal on comprehensive rules for trustworthy AI.*
URL: www.europarl.europa.eu/news/en/press-room/20231206IPR15699/artificial-intelligence-act-deal-on-comprehensive-rules-for-trustworthy-ai

[427] World Economic Forum (2023), *Everything you need to know about AI in 2023: the 6 must-read blogs.*
URL: https://www.weforum.org/agenda/2023/11/ai-2023-governance-summit/. See also : Associated Press News (2023), *Europe reaches a deal on the world's first comprehensive AI rules.*
URL: https://apnews.com/article/ai-act-europe-regulation-59466a4d8fd3597b04542ef25831322c

[428] Filipova, I. A. (2024). *Legal Regulation of Artificial Intelligence: Experience of China. Journal of Digital Technologies and Law*, 2(1), 46-73.
URL: https://doi.org/10.21202/jdtl.2024.4

[429] United Nations General Assembly (UNGA). Resolution A/78/L.49 adopted on 21 March 2024 without a vote https://undocs.org/A/78/L.49

data. The resolution calls for bridging the digital divide in AI and other technologies, both between and within countries, to achieve the 17 Sustainable Development Goals (SDGs)[430].

The resolution outlines measures for ensuring data privacy, advocating for the safe development of AI, especially when dealing with sensitive personal information such as medical, biometric, or financial data. Member states and relevant stakeholders are encouraged to monitor AI systems for risks and assess their impact on data security and privacy protections throughout the entire lifecycle of these systems (6.e, p5/8). The repeated references to "the entire lifecycle" imply a comprehensive regulatory approach to AI, commencing with the "training" phase, where attention to data privacy in selection and usage is critical, and extending through technological development to consumer delivery. Impact assessments on privacy and detailed product testing during the development process are proposed as mechanisms for data protection and safeguarding fundamental rights to privacy[431]. The document also affirms that states should execute their responsibilities in accordance with national legislation, thus providing substantial latitude for states in implementation.

Conclusion

In the context of global climate change, population growth, and increasing water scarcity, AI emerges as a crucial tool for ensuring a sustainable future in water resource management. The use of AI not only aids in effectively addressing existing water supply challenges but also opens up new opportunities for achieving water security and sustainable development. For instance, smart irrigation systems can significantly enhance water distribution efficiency in agriculture, while leak detection systems can help reduce water losses.

At the same time, integrating AI into water resource management presents several challenges that must be addressed. Firstly, the need for high-quality data for training and optimizing AI models can be hindered by a lack of or incomplete data availability. Secondly, the implementation of AI technologies involves significant costs, which can be a barrier to widespread adoption, particularly in developing countries or regions with limited resources. Thirdly, issues of ethics and data privacy arise, necessitating careful regulation and adherence to standards to prevent misuse and protect user rights.

Therefore, the rational application of digital technologies should be coupled with adherence to ethical standards, effective data and resource management, and continuous monitoring and adjustment of methods. It is crucial that the integration of AI into water resource management is approached with awareness and balance, focusing on maximizing its potential benefits while minimizing possible risks and negative consequences.

12.5. Green Hydrogen: Global and Central Asian Development Trends

Prepared by M.S. Valieva, D.R. Ziganshina (SIC ICWC)

In recent decades, the global community has grappled with the pressing challenge of climate change, necessitating significant societal transformations. This includes a decisive shift away from fossil fuels towards renewable energy sources (RES), increased energy efficiency, and widespread electrification. In this context, green hydrogen – hydrogen produced using renewable energy – emerges as a pivotal component in the transition to a decarbonized future.

Green hydrogen, as a relatively new technology, is subject to intense scrutiny. Many aspects of its production remain unclear or insufficiently studied, including land use implications, actual greenhouse gas emissions, and the potential to extend the lifespan of fossil fuel power plants. This thematic review offers a concise overview of global and Central Asian trends in green hydrogen development, with a particular focus on its potential impact on water resources.

Hydrogen and its types

Hydrogen is the most common chemical element on Earth, which is found in water, air and solids. In world practice, there is a conditional classification of hydrogen by color, depending on the environmental friendliness of the process of its production. They distinguish:

- *gray hydrogen*, which produces the largest amount of carbon dioxide from coal or methane;
- *pink/red/yellow* hydrogen produced by atomic energy;
- *turquoise/blue* hydrogen produced from natural gas using Carbon Capture, Utilization and Storage (CCUS) technology or without carbon dioxide release (experimental pyrolysis);

[430] Kohtyulina I., Smirnov A. (2024), *Первая Резолюция Генассамблеи ООН по искусственному интеллекту. Пройдет ли Резолюция тест Тьюринга в новых реалиях? (The first Resolution of the UN General Assembly on artificial intelligence. Will the Resolution pass the Turing test in the new realities?)*. URL: https://interaffairs.ru/news/show/45318

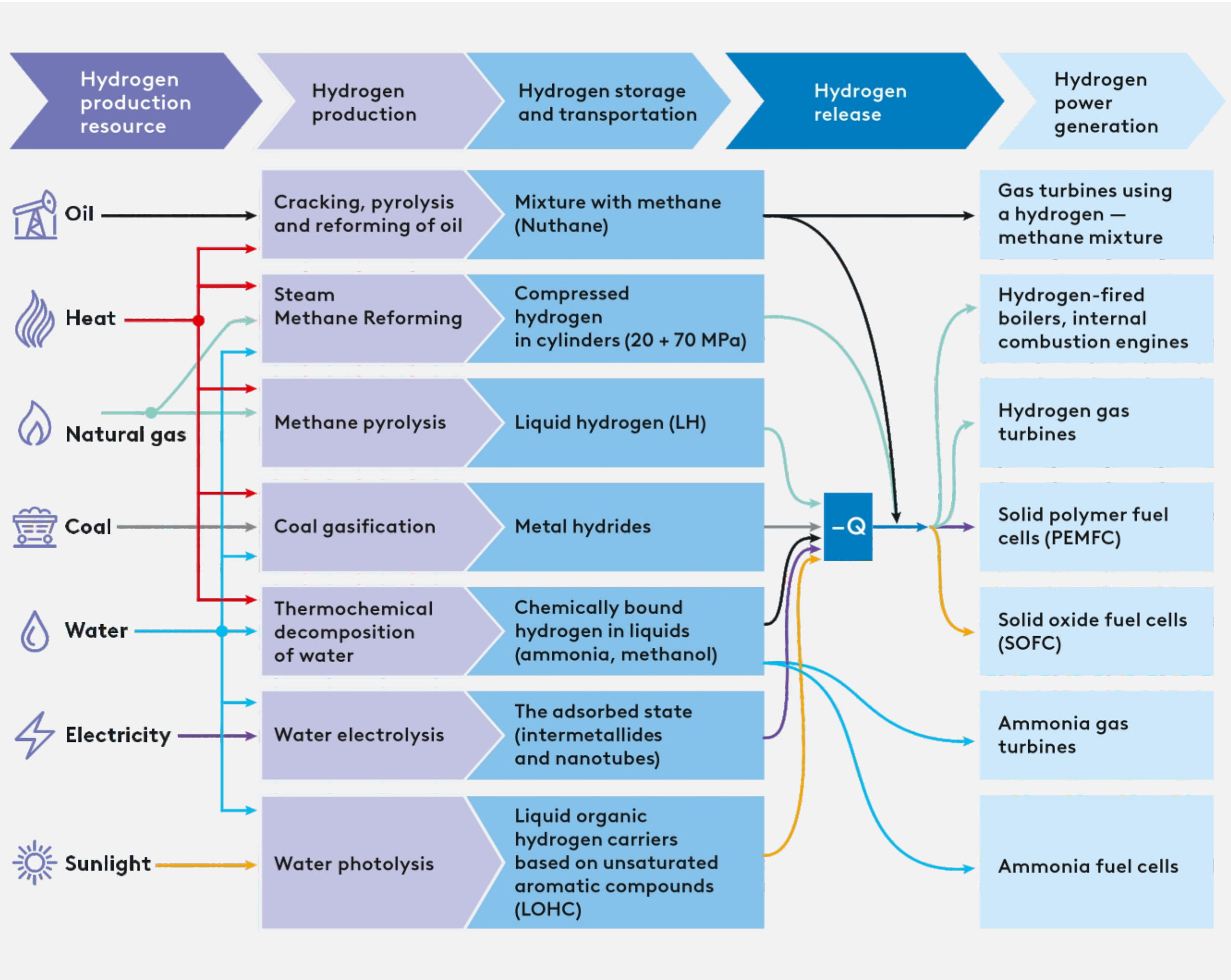
[431] Khelif M. (2024), *United Nations AI Resolution: a Significant Global Policy Effort to Harness the Technology for Sustainable Development.* URL: https://executive.graduateinstitute.ch/communications/news/united-nations-ai-resolution-significant-global-policy-effort-harness

- *green* hydrogen, which is produced by electrolysis of water using electricity produced from renewable energy sources. It is considered the most environmentally friendly and clean.

There are other types of hydrogen classification, including "low carbon hydrogen", which refers to hydrogen based on fossil fuels with CO_2 capture and hydrogen based on electricity.

Currently, hydrogen production worldwide is predominantly based on organic fuels – natural gas, coal, and oil – accounting for 96% of total production. Only 4% of hydrogen is produced through water electrolysis. The figure below illustrates the main technological pathways of hydrogen energy, from production to its utilization as an energy carrier. However, with the growing need to transition away from fossil fuels, the demand for and production of green hydrogen is steadily increasing.

The main technological chains of hydrogen energy



Source: Green Technologies for Eurasia's Sustainable Future/Edited by Evgeny Vinokurov. Moscow: Eurasian Development Bank, Global Energy Association, 2021
URL: https://eabr.org/upload/iblock/d4f/EDB_-GLEN_2021_Report_Green-Technologies_eng.pdf

Growing demand for green hydrogen

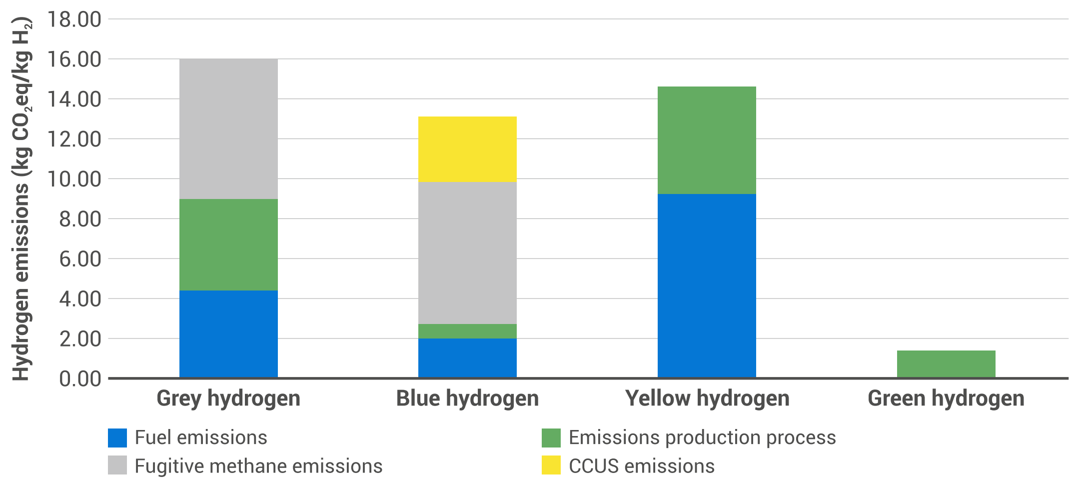
Global hydrogen consumption in 2022 reached 95 million tons, representing an increase of nearly 3% compared to 2021. Significant growth was observed across all major consumer regions, except Europe, where industrial activity was impacted by a sharp rise in natural gas prices. [432]

The International Energy Agency (IEA) estimates that global hydrogen demand could reach 115 million tons by 2030, with less than 2 million tons driven by new applications. This falls short of the 130 million tons

[432] International Energy Agency (2023), *Global hydrogen review 2023*.
URL: https://www.iea.org/reports/global-hydrogen-review-2023/executive-summary

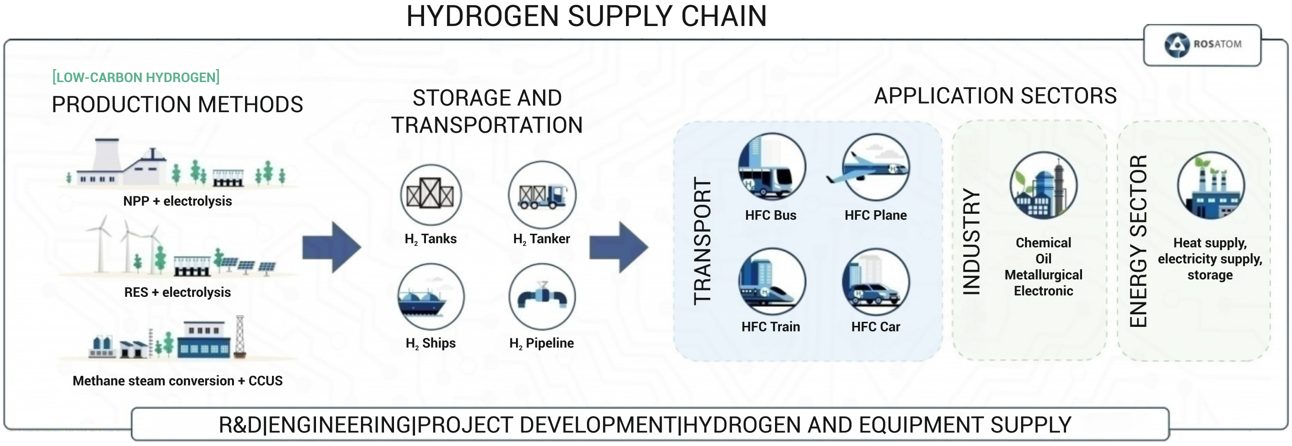
(25% from new uses) required to meet countries' existing climate commitments and the 200 million tons needed by 2030 to align with achieving net-zero emissions by 2050.[433] According to McKinsey's forecasts,[434] demand for pure hydrogen could rise to between 125 and 585 million tons per year by 2050.[435]

Comparison of emissions from various hydrogen (H_2) production methods



Source: Francisco L. D. Simões and Diogo M. F. Santos (2024), *A SWOT Analysis of the Green Hydrogen Market*. URL: https://www.mdpi.com/1996-1073/17/13/3114

HYDROGEN SUPPLY CHAIN



Source: Rosatom. URL: https://www.eastrussia.ru/material/stechenie-vodorodnykh-obstoyatelstv/

Green hydrogen: advantages and disadvantages

Like most energy sources, green hydrogen has both advantages and disadvantages. Among the key advantages of green hydrogen are the following:

- *Environmental friendliness.* Green hydrogen is produced using renewable energy sources such as solar, wind and hydropower, without the emmission of harmful greenhouse gases, which ensures its purity and sustainability as an energy source;

- *Wide range of applications in various industries thanks to its versatility and stability.* Green hydrogen can provide fuel for such hard-to-carbonize heavy industries as steel, chemical and cement industries that cannot use solar or wind energy, shipping, aviation and ammonia production. A higher energy

[433] International Energy Agency (2022), *Global hydrogen review 2022*. URL: https://iea.blob.core.windows.net/assets/c5bc75b1-9e4d-460d-9056-6e8e626a11c4/GlobalHydrogenReview2022.pdf

[434] McKinsey & Company is an international consulting company specializing in solving problems related to strategic management

[435] McKinsey & Company (2024), *Global energy perspective 2023: Hydrogen outlook*. URL: https://www.mckinsey.com/industries/oil-and-gas/our-insights/global-energy-perspective-2023-hydrogen-outlook

density than that of batteries makes it possible to use hydrogen for long-haul freight transportation;

- *The possibility of storage and use as an energy carrier.* During peak production periods, excess electricity generated from the sun and wind can be used to produce hydrogen, which can be stored indefinitely. When production levels drop or demand increases sharply, the generator converts the stored hydrogen into electricity, which is supplied to the grid, ensuring a continuous and stable energy supply[436]. In addition, hydrogen can be used as a clean fuel for various types of transport, such as cars, trucks, buses and even hydrogen fuel cell trains. Fast refueling capabilities make green hydrogen a viable alternative to fossil fuels.

- *The possibility of transportation through the existing infrastructure.* Like natural gas, green hydrogen can be safely delivered to the end user through a pipeline. Using the existing natural gas supply network and laying new pipelines where necessary, it is possible to create a reliable national transportation network for hydrogen, the carbon-neutral energy carrier of the future. In particular, Gasunie, which is engaged in the safe transportation of natural gas throughout the Netherlands, has also accumulated many years of experience in transporting hydrogen between two companies in the province of Zealand through an existing decommissioned gas pipeline[437].

- *The highest efficiency of all types of pure hydrogen in terms of water use.* On average, hydrogen production by electrolysis with a proton exchange membrane (PEM) has the lowest water consumption – about 17.5 l/kg. This is followed by alkaline electrolysis with a water consumption rate of 22.3 l/kg. For comparison, the method of steam conversion of methane – carbon capture, utilization and storage (SMR-CCUS) – uses 32.2 l/kg, and autothermal reforming (ATR)-CCUS uses 24.2 l/kg[438].

Despite the many advantages of green hydrogen as an energy source, its **potential disadvantages** must also be taken into account:

- *Higher cost of green hydrogen production compared to hydrogen derived from fossil fuels.* This cost disparity stems from the high expense of renewable energy sources and the technological processes involved in water electrolysis. For instance, electrolyzers can cost up to six times more than natural gas-based equipment. The production cost of green hydrogen ranges from $2.5 to $5 per kilogram, compared to $1.50-$3.50/kg for blue hydrogen and $1.50/kg for gray hydrogen.[439] According to the IEA's 2019 analysis, producing hydrogen from fossil fuels is expected to remain the most cost-effective option until 2030. Lowering the production cost of green hydrogen is essential for scaling up access to clean hydrogen.[440] High production costs for green hydrogen pose a significant challenge to the European Union's ambitious goals as a leading player in the hydrogen market. Under the REPowerEU plan adopted in 2022, Europe aimed to produce and import 10 million tons of green hydrogen by 2030. However, in April 2024, the CEO of TotalEnergies stated at the World Economic Forum that achieving these targets is unrealistic due to the nascent stage of market development and the high costs associated with green hydrogen production.[441] The European Court of Auditors has confirmed that the EU's aspirations are based on "political will" and not on realistic assessments[442].

- *The cost of hydrogen.* In July 2024, FTI Consulting[443] presented a "Green Hydrogen Global Market Price Model" with calculations of the cost of producing and delivering green hydrogen in various ways, including marine transport and pipeline systems. According to the data, by 2030 the average price of green hydrogen may reach $5.3 per kg[444]. The Dutch Institute TNO[445] conducted (2024) a study of prices for hydrogen production in the Netherlands, analyzing 14 projects implemented by 11 major market participants. It turned out that the cost of European-made electrolysis plants is significantly higher than expected: €3,050 per kW for a 100 MW plant and €2,630 per kW for 200 MW. In recent years, production costs for green hydrogen have risen due to increases in energy prices, material and labor costs, higher interest rates, and transportation tariffs. Consequently, the current price of green hydrogen in the Netherlands

[436] Vinci (2024), *What are the uses of hydrogen in today's world and its future?* URL: https://emag.vinci.com/en/what-are-uses-hydrogen-todays-world-and-future

[437] Gasunie (n.d.), *Hydrogen through natural gas pipelines: safe and sustainable.* URL: https://www.gasunie.nl/en/expertise/hydrogen/hydrogen-through-gas-pipelines-safe-and-sustainable#:~:text=This%20project%20has%20demonstrated%20that,diverted)%20on%20various%20pipeline%20sections

[438] IRENA and Bluerisk (2023), *Water for hydrogen production, International Renewable Energy Agency*, Bluerisk, Abu Dhabi, United Arab Emirates. URL: www.irena.org/-/media/Files/IRENA/Agency/Publication/2023/Dec/IRENA_Bluerisk_Water_for_hydrogen_production_2023.pdf

[439] Scita, Rossana and Raimondi, Pier Paolo and Noussan, Michel (2020), *Green Hydrogen: The Holy Grail of Decarbonisation? An Analysis of the Technical and Geopolitical Implications of the Future Hydrogen Economy.* URL: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3709789

[440] Shayan Sadeghi, Samane Ghandehariun, Marc A. Rosen (2020), *Comparative economic and life cycle assessment of solar-based hydrogen production for oil and gas industries.* URL: https://www.sciencedirect.com/science/article/abs/pii/S0360544220314547

[441] YouTube (2024), *The Rise of Green Molecules in the World Economic Forum* [Video]. URL: https://www.youtube.com/live/ys7LymlFj2M

[442] Financial Times (2024), *EU hydrogen targets are 'unrealistic', says audit body*. URL: https://www.ft.com/content/6ea87a1c-1413-4b08-a953-a33dc729dd3c

[443] FTI Consulting is a business consulting firm founded in 1982 and headquartered in Washington, DC, USA

[444] FTI Consulting (2024), *Green hydrogen global market price model.* URL: https://www.fticonsulting.com/-/media/files/insights/reports/2024/jul/green-hydrogen-global-market-price-model.pdf

[445] Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (TNO; English: Dutch Organization for Applied Scientific Research) is an independent research organization in the Netherlands specializing in applied science

ranges from €12 to €14 per kilogram, significantly exceeding initial forecasts.[446]

■ *Problems of hydrogen storage systems*. The shift toward large-scale industrial production of green hydrogen, coupled with its widespread distribution, could address the challenge of storage. According to the EnergyNet research center, a significant reduction in the cost of storing liquefied hydrogen is anticipated globally after 2025, with prices expected to nearly halve from $2 to $0.9 per kilogram. Storing hydrogen in the form of ammonia is projected to be the most economical option, with storage costs dropping to approximately $0.1 per kilogram by 2025.

■ *High power consumption*. The production of hydrogen, particularly green hydrogen, requires more energy compared to the production of other fuels.

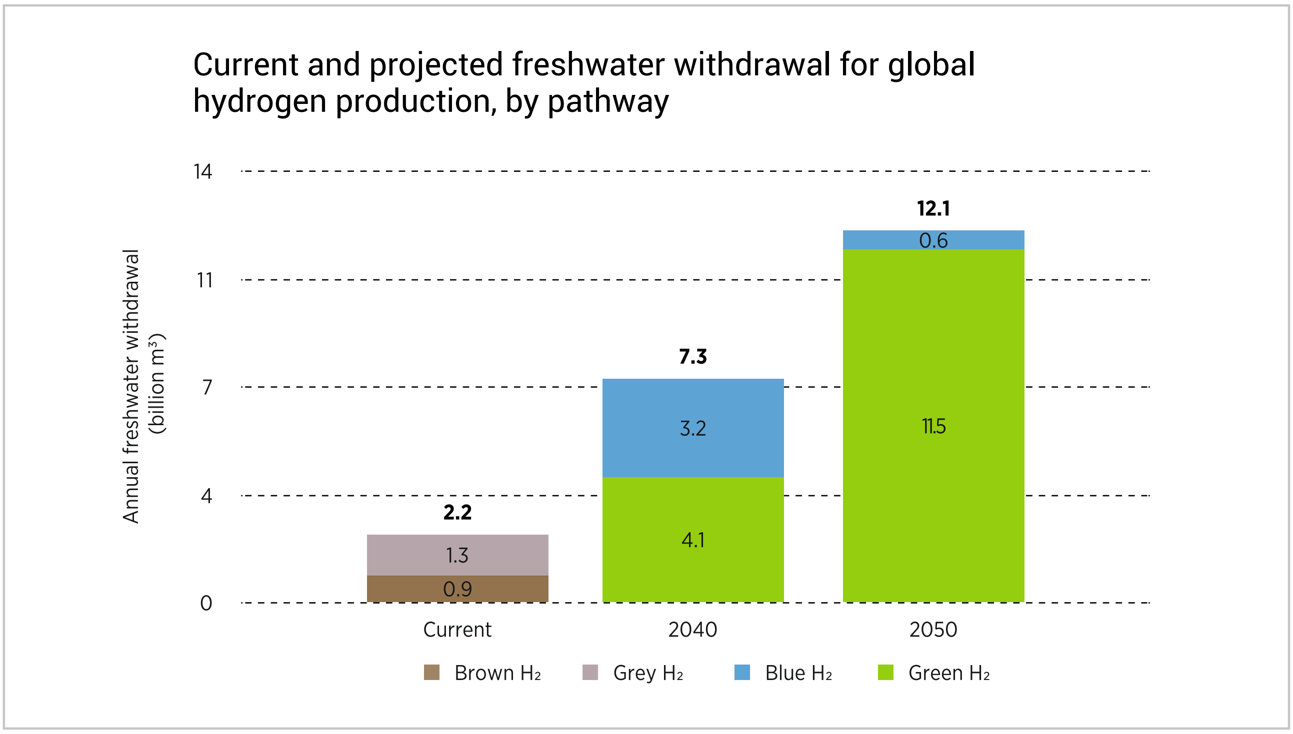
■ *Large volume*. The volume of green hydrogen is nearly four times larger than that of natural gas. To store green hydrogen, it must either be compressed to a pressure 700 times higher than normal atmospheric pressure or cooled to -253°C, which is close to absolute zero.[447]

■ *Infrastructure*. Hydrogen atoms are small and can sometimes seep through steel. Therefore, some existing pipelines may need to be upgraded.

■ *Significant amounts of water used for electrolysis*, which poses a problem for water-scarce regions. Water is required not only as a raw material for production but also for cooling in all types of hydrogen production. The water consumption for producing 1 kg of renewable hydrogen ranges from 20 to 30 liters per kilogram (untreated water).[448] OECD estimates this as about 1 billion liters annually with a production goal of 40 million tons per year, which is one of the targets for increasing pure hydrogen production by 2030.[449]

According to IRENA, approximately 2.2 billion m^3 of freshwater are used annually for global hydrogen production, accounting for 0.6% of the total volume of freshwater withdrawn by the energy sector.

Gray hydrogen production accounts for about 59% of the world's freshwater consumption, while brown hydrogen accounts for 40%, with the remainder attributed to green and blue hydrogen. Freshwater consumption for global hydrogen production could more than triple by 2040 and increase sixfold by 2050 compared to 2023 (see the figure below)[450]. Additionally, rising water demand for hydrogen production may intensify competition between sectors, such as agriculture and household consumption, potentially threatening food security and impacting the well-being of populations.



[446] TNO (2024), *Evaluation of the levelised cost of hydrogen based on proposed electrolyser projects in the Netherlands*. URL: https://publications.tno.nl/publication/34642511/mzKCln/TNO-2024-R10766.pdf

[447] ABC News (2021), *What is green hydrogen, how is it made and will it be the fuel of the future?* URL: https://www.abc.net.au/news/science/2021-01-23/green-hydrogen-renewable-energy-climate-emissions-explainer/13081872

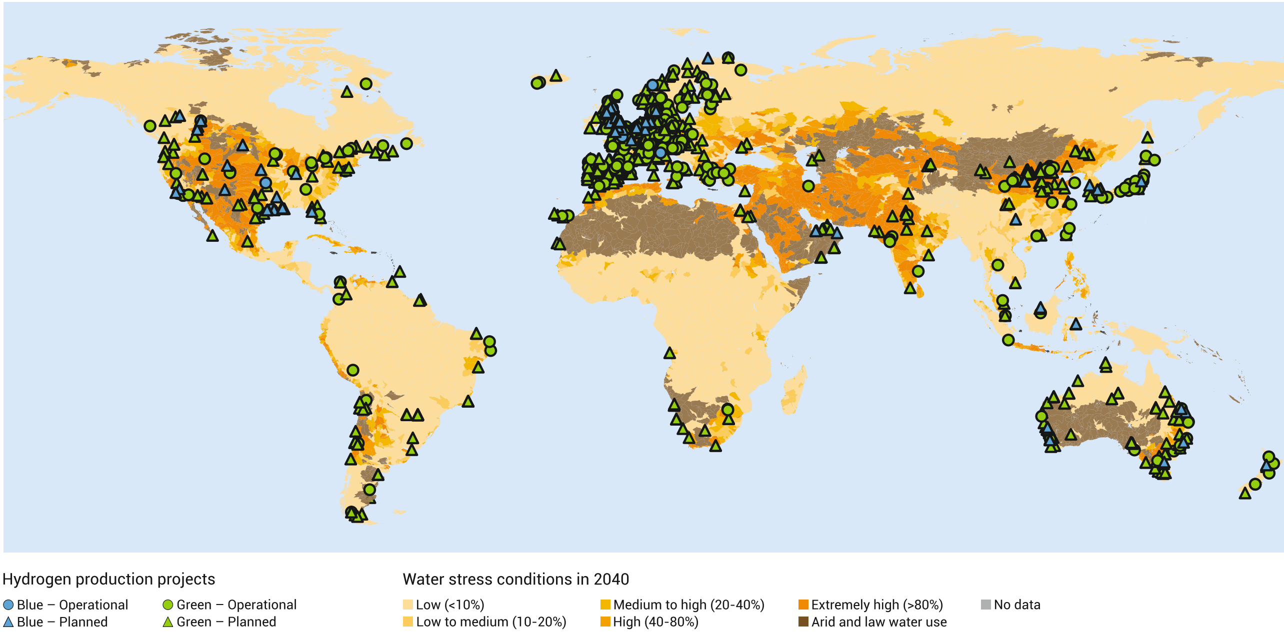
[448] Peline Atamer (2023), *Sustainable water use for green hydrogen production: preliminary insights from OECD work in Mongolia*

[449] Peline Atamer (2023), *Sustainable water use for green hydrogen production: preliminary insights from OECD work in Mongolia*

[450] IRENA and Bluerisk (2023), *Water for hydrogen production, International Renewable Energy Agency, Bluerisk, Abu Dhabi, United Arab Emirates*. URL: www.irena.org/-/media/Files/IRENA/Agency/Publication/2023/Dec/IRENA_Bluerisk_Water_for_hydrogen_production_2023.pdf

Although the use of deionized water produced by desalination plants can reduce the need for fresh water, it also causes the need to discharge residual brine into water sources and soil[451]. In addition, despite the generally insignificant use of water for hydrogen production at the global level, it is important to take into account local conditions. More than 35% of the world's green and blue hydrogen production capacities (in operation and planned) are located in regions with acute water shortages[452].

Global water stress conditions and green and blue hydrogen project locations for 2040



- *Low demand for green hydrogen*. Experts suggest that the high cost of equipment required for hydrogen use and the challenges surrounding its supply infrastructure have resulted in a lack of significant demand.[453] In particular, the passenger car sector saw a 30.2% decline in global sales of hydrogen fuel cell vehicles in 2023 compared to 2022.[454] Additionally, a recent study indicates that hydrogen fuel cell trucks are unlikely to compete with electric vehicles on cost[455]. In 2024, McKinsey revised its forecast for the hydrogen market's development through 2050, reducing it by 10-25% compared to previous estimates. According to the updated report, hydrogen consumption by 2050 could range from 180 to 350 million tons per year, with 50-70% of this volume expected to be green hydrogen.[456]

- *Explosion hazard*. Green hydrogen is a highly flammable substance, and its storage and transportation require the use of high-pressure containers and pipelines. In the event of leaks or explosions, these systems could pose a significant threat to public health and safety. Therefore, strict safety measures are essential to prevent such incidents.

- *Impact on climate change*. In the event of leakage into the atmosphere, hydrogen can enhance the heat-trapping effect of methane and act as a greenhouse gas, leading to the formation of water vapor in the upper atmosphere. Additionally, studies indicate that burning hydrogen in power plants increases the formation of nitrogen oxides (Nox), pollutants that contribute to smog, harm public health, and accelerate global warming[457].

[451] Hurwitz Z., Bujak N., Tapia M., Daza E., Gischler Ch. (2023), *Key aspects for managing the environmental and social risks of green hydrogen, Inter-American Development Bank.*
URL: https://blogs.iadb.org/sostenibilidad/en/key-aspects-for-managing-the-environmental-and-social-risks-of-green-hydrogen/

[452] IRENA and Bluerisk (2023), *Water for hydrogen production, International Renewable Energy Agency, Bluerisk, Abu Dhabi, United Arab Emirates.*
URL: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2023/Dec/IRENA_Bluerisk_Water_for_hydrogen_production_2023.pdf

[453] David R Baker (2024), *Why almost nobody is buying green hydrogen, Bloomberg*.
URL: https://www.japantimes.co.jp/environment/2024/08/14/energy/nobody-buying-green-hydrogen/

[454] RenEn (2024), *Продажи водородных автомобилей в мире упали на 30,2% в 2023 г.*
URL: https://renen.ru/prodazhi-vodorodnyh-avtomobilej-v-mire-upali-na-30-2-v-2023-godu/

[455] International Transport Forum (2024), *Decarbonising Europe's trucks: Minimise cost and uncertainty.*
URL: https://www.itf-oecd.org/sites/default/files/docs/decarbonising-europes-trucks-minimise-cost-uncertainty.pdf

[456] McKinsey & Company (2024), *Global energy perspective 2024.*
URL: https://www.mckinsey.com/industries/energy and materials/our insights/global-energy-perspective

[457] Kari Lydersen (2024), Scientists warn a poorly managed hydrogen rush could make climate change worse.
URL: https://energynews.us/2024/02/28/scientists-warn-a-poorly-managed-hydrogen-rush-could-make-climate-change-worse/#:~:text=Hydrogen%20is%20%E2%80%9Can%20indirect%20global,of%20methane%20in%20the%20atmosphere

■ *Green hydrogen and hydropower plants.* Environmental and human rights organizations warn that the growth of the green hydrogen industry could lead to a new wave of large-scale hydroelectric power plant construction worldwide. This trend is linked to significant environmental, social, and economic issues, including ecosystem destruction, displacement of populations, high capital costs, and the risk of man-made disasters.[458] Environmentalists from the Rivers Without Borders Public Foundation, in their review of the draft Concept for the Development of Hydrogen Energy in the Republic of Kazakhstan, argue that the country's energy-intensive hydrogen production is primarily aimed at justifying the construction of new energy facilities, such as large hydroelectric and nuclear power plants. These projects could have significant negative impacts on the environment and biodiversity.[459] Reservoirs created for hydroelectric power plants are a source of greenhouse gas emissions, particularly methane, which in the near future will have an emissions impact 84 times greater than that of carbon dioxide.[460] Therefore, to ensure the optimal use of hydroelectric power plants, careful planning and the development of strategies to minimize their negative impact while maximizing their benefits are essential.

Global development of green hydrogen

Given the potential of green hydrogen as an environmentally friendly and low-carbon method of energy production, storage, and transmission, many of the world's leading countries have created opportunities for its development in recent years.

In 2017, ***Japan*** became the first country in the world to adopt a national hydrogen strategy, which was updated in 2023. The updated strategy identifies nine key technologies, including fuel cells and water electrolysis devices. It was also decided to invest more than 15 trillion yen ($98.8 billion) over the next 15 years and increase hydrogen consumption to 12 million tons per year by 2040[461].

Germany plans to invest over €10 billion in the hydrogen sector by 2023, including €7 billion for "market launch" (creating framework conditions and stimulating domestic demand), €2 billion for international cooperation, and another €1 billion for the needs of the industry, which in turn is expected to implement hydrogen technologies to potentially become the world's largest exporter.[462] The German government views hydrogen energy as the most effective way to utilize existing energy sources.[463]

It is important to note that in recent years, there has been a shift in leadership within the hydrogen economy. The BRICS countries are taking the lead, showcasing significant achievements in technological development, project implementation, and the growth of domestic markets, as well as in the volume of export agreements.[464]

China, as the world's largest hydrogen producer and with the world's largest renewable energy capacity, is striving to create an integrated hydrogen industry encompassing transportation, energy storage and the industrial sector. By 2035, the country plans to increase the share of green hydrogen in its energy mix.

According to the "Green Hydrogen Energy Development Plan for 2021-2035," China aims to achieve annual hydrogen production from renewable energy sources of 0.1-0.2 million tons. At the same time, approximately 60% of the world's electrolyser production capacity is concentrated in China, with costs significantly lower than those of European counterparts.[465]

In 2020, ***South Korea*** set standards for clean hydrogen energy, and in 2021 it defined the criteria for certification of green hydrogen. The country is actively developing infrastructure for hydrogen vehicles, charging stations and fuel cells for the mass deployment of hydrogen technologies.

As of 2020, 99% of hydrogen in the ***USA*** was produced from fossil fuels. To stimulate the production of "clean hydrogen" (produced with low or zero carbon emissions), the Bipartisan Infrastructure Law was passed in 2021, allocating over $9.5 billion in direct investments for clean hydrogen initiatives. In 2022, the tax credit for its production was reduced.[466] In 2023, the National

[458] International Rivers (2022), *Green hydrogen factsheet.*
URL: https://www.internationalrivers.org/wp content/uploads/sites/86/2022/07/Green-Hydrogen-Factsheet.pdf

[459] Central Asia Climate Portal (2024), *Kazakhstan may ban the use of hydroelectric power plants for the production of green hydrogen.*
URL: https://centralasiaclimateportal.org/kazakhstan-may-ban-the-use-of-hydroelectric-power-plants-for-the-production-of-green-hydrogen/

[460] International Rivers (2022), *Green hydrogen factsheet.*
URL: https://www.internationalrivers.org/wp-content/uploads/sites/86/2022/07/Green-Hydrogen-Factsheet.pdf; RenEn (2016), *Гидроэлектростанции и выбросы парниковых газов.* URL: https://renen.ru/gidroelektrostantsii-i-vybrosy-parnikovyh-gazov/

[461] Ministry of Economy, *Trade and Industry (2023), Basic Hydrogen Strategy of Japan.*
URL: www.meti.go.jp/shingikai/enecho/shoene_shinene/suiso_seisaku/pdf/20230606_5.pdf

[462] РБК (2021), *Водородная энергетика России и Европы: перспективы рынка на $700 млрд.*
URL: https://trends.rbc.ru/trends/green/5ef46e379a7947a89c25170d

[463] *Green Technologies for Eurasia's Sustainable Future*/Edited by Evgeny Vinokurov. Moscow: Eurasian Development Bank, Global Energy Association, 2021. URL: https://eabr.org/upload/iblock/d4f/EDB_-GLEN_2021_Report_Green-Technologies_eng.pdf

[464] Forbes (2024), *«Водородная эйфория» закончилась: почему этот источник энергии не спасет планету.*
URL: https://www.forbes.ru/sustainability/522323-vodorodnaa-ejforia-zakoncilas-pocemu-etot-istocnik-energii-ne-spaset-planetu

[465] Forbes (2024), *«Водородная эйфория» закончилась: почему этот источник энергии не спасет планету.*
URL: https://www.forbes.ru/sustainability/522323-vodorodnaa-ejforia-zakoncilas-pocemu-etot-istocnik-energii-ne-spaset-planetu

[466] WRI (2023), *Unlocking Clean Hydrogen Investments in U.S. Climate Policy.* URL: www.wri.org/update/clean-hydrogen-investments-bil-ira

Strategy and Roadmap for Clean Hydrogen were adopted.[467]

The Hydrogen Strategy of the ***European Union***, adopted in 2020 (COM/2020/301), established a foundation for supporting the production and use of renewable and low-carbon hydrogen.[468] The European Union plans to invest $430 billion in clean hydrogen by 2030.

In 2023, ***India*** approved the National Mission for Green Hydrogen with the goal of producing at least 5 million tons of clean hydrogen annually, accompanied by an increase in renewable energy capacity of 125 GW through over €2.24 billion in investments.[469]

The Ministry of Energy of the ***Russian Federation*** has developed a Roadmap titled "Development of Hydrogen Energy in Russia" for 2020-2024, which served as the foundation for the Action Plan approved by RF Government Decree No.2634-r on 12.10.2020. Russia plans to produce and export hydrogen in line with the global trend of phasing out hydrocarbon energy. The country's competitive advantages include its vast energy reserves, proximity to potential consumers (such as EU countries, China, and Japan), and the existing transportation infrastructure.[470]

Central Asian development of green hydrogen

Kazakhstan is an energy-surplus country and an important regional exporter of coal, oil, and gas, with growing production rates. Coal dominates the electricity and heat supply, contributing to a relatively rapid increase in greenhouse gas emissions. The variety of resources available in the country for low-carbon hydrogen production presents opportunities for synergy and the accelerated development of Kazakhstan's hydrogen economy, driven by economies of scale.[471]

The development of hydrogen energy in Kazakhstan can help balance the intermittent electricity production from renewable energy sources, meet electricity demand, and enhance network stability, while also contributing to the decarbonization of various emission-intensive sectors (such as industry, transport, and energy). According to UNECE forecasts, the potential for hydrogen production from water via electrolysis using renewable energy sources in Kazakhstan by 2040 ranges from 85 to 1,464 thousand tons.[472]

In line with the Strategy for Achieving Carbon Neutrality of the Republic of Kazakhstan by 2060 and the National Development Plan through 2025, the country has approved the Concept of Hydrogen Energy Development until 2030.[473] The document highlights hydrogen as a key element in the transition to a low-carbon economy, with the potential to decarbonize industrial processes and transport. The expected outcome of the Concept is to achieve hydrogen production of 10 thousand tons by 2027. By 2029, the planned production volume is expected to reach 18 thousand tons per year, with a target of 25 thousand tons by 2030, with at least 50% of that being green hydrogen. A key goal is also to reduce carbon dioxide emissions by 0.1% by 2030 through the use of hydrogen across various sectors of the economy. Additionally, Kazakhstan plans to export 15 thousand tons of hydrogen per year to partner countries by 2030. As part of international cooperation, five agreements on joint hydrogen energy projects are expected to be concluded by 2030. The introduction of hydrogen buses is also planned for at least three cities by that date.[474]

A Competence Center for Hydrogen Energy was established under the National Company KazMunaiGas, which has been functioning as a research hub for hydrogen energy technologies since April 2022.[475] In 2021, a Framework Agreement was signed between the Government of the Republic of Kazakhstan and NEH Eurasia GmbH (Germany) on the basic principles for implementing renewable energy projects and producing green hydrogen in the Mangystau region. The plan includes the construction of a solar and wind farm to generate 40 GW of electricity, which will be used for hydrogen production via electrolysis using desalinated water. Additionally, Kazakhstan and the European

[467] U.S. Department of Energy (2021), *Clean hydrogen strategy and roadmap.*
URL: www.hydrogen.energy.gov/library/roadmaps-vision/clean hydrogen-strategy-roadmap; See also: U.S. Department of Energy, Office of Fossil Energy, *Hydrogen Strategy – Enabling a Low-Carbon Economy.*
URL: www.energy.gov/sites/prod/files/2020/07/f76/USDOE_FE_Hydrogen_Strategy_July2020.pdf

[468] European Commission (n.d.), *Hydrogen.* URL: https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen_en

[469] Green Hydrogen Organisation (n.d.), India. URL:https://gh2.org/countries/india

[470] *Green Technologies for Eurasia's Sustainable Future*/Edited by Evgeny Vinokurov. Moscow: Eurasian Development Bank, Global Energy Association, 2021. URL: https://eabr.org/upload/iblock/d4f/EDB_-GLEN_2021_Report_Green-Technologies_eng.pdf

[471] United Nations Economic Commission For Europe (2023), *Low-carbon hydrogen production in the CIS countries and its role in the development of the hydrogen ecosystem and export potential.*
URL: https://unece.org/sites/default/files/2023 03/EN_Sustainable%20Hydrogen%20Production%20Pathways_final_0.pdf

[472] United Nations Economic Commission For Europe (2023), *Low-carbon hydrogen production in the CIS countries and its role in the development of the hydrogen ecosystem and export potential.*
URL: https://unece.org/sites/default/files/2023 03/EN_Sustainable%20Hydrogen%20Production%20Pathways_final_0.pdf

[473] Order of the Minister of Energy of the Republic of Kazakhstan (September 27, 2024) No.342. *"On approval of the Concept of development of hydrogen energy in the Republic of Kazakhstan until 2030".*
URL: https://online.zakon.kz/Document/?doc_id=38912454&pos=5;-106#pos=5;-106

[474] Zakon.kz (2024), *Концепция развития водородной энергетики утвердили в Казахстане.*
URL: https://www.zakon.kz/pravo/6452721-kontseptsiyu-razvitiya-vodorodnoy-energetiki-utverdili-v-kazakhstane.html

[475] Zholdayakova, S., Y. Abuov, D. Zhakupov, B. Suleimenova, and A. Kim (2022), *Toward Hydrogen Economy in Kazakhstan*, Asian Development Bank Institute. URL: https://doi.org/10.56506/IWLU3832

Union have signed a memorandum on strategic partnership in the fields of sustainable raw materials, batteries, and green hydrogen value chains.

Kyrgyzstan is an energy-deficient country, meeting only 51% of its electricity needs from domestic resources, primarily hydroelectric power plants. The country has significant potential for developing hydro and solar energy, which could be used to produce between 5,000 and 145,000 tons of low-carbon hydrogen per year.[476] The relatively low cost of hydropower generation in Kyrgyzstan (2-2.3 cents per kWh) helps reduce the cost of producing green hydrogen.[477] While there are currently no active green hydrogen projects in Kyrgyzstan, the President has expressed interest in developing cooperation with Germany in the field of green hydrogen production and use.[478]

Tajikistan is an energy-deficient country with limited fossil energy resources, but it meets 90% of its electricity needs through hydropower. The country possesses vast potential in hydropower, though it has not yet explored its solar energy potential. The estimated share of the country's territory that could be covered by photovoltaic installations to generate the equivalent of the annual electricity consumption is just 0.074%. With the development of these resources, Tajikistan is projected to have the potential to produce between 9,000 and 204,000 tons of low-carbon hydrogen per year by 2040[479]. According to the leadership of the Ministry of Energy and Water Resources, Tajikistan plans to produce 1 million tons of green hydrogen annually by 2040, both for domestic consumption and exports to Central Asian countries.[480] Currently, no projects have been completed.

Turkmenistan is an energy-rich country and a major exporter of natural gas, which dominates its energy sector, accounting for nearly 100% of electricity production. The share of renewable energy in the country's energy mix remains minimal. However, Turkmenistan holds significant potential for low-carbon energy production. Blue hydrogen can be produced from natural gas using carbon capture, utilization, and storage (CCUS) technologies.[481] The country's relatively modern gas pipelines present opportunities for hydrogen injection and retrofitting.[482] Additionally, by harnessing its untapped renewable energy resources, including offshore wind in the Caspian Sea, Turkmenistan could establish green hydrogen production through water electrolysis powered by renewable energy. Projections estimate that the country could produce between 6,000 and 321,000 tons of hydrogen annually, paving the way for a sustainable energy future. Low-carbon hydrogen could replace petroleum products in the transport sector and position Turkmenistan as a key player in future export projects, particularly to markets like China.[483] Since 2022, a draft "Roadmap for the Development of Green Hydrogen Energy in Turkmenistan"[484] has been under discussion. However, no projects have been implemented yet.

Uzbekistan is an energy-rich country, a major producer and exporter of natural gas, and a significant producer of oil and coal to meet domestic demand. The country also possesses substantial potential for renewable energy, particularly solar power, with a technical capacity estimated at 180 million tons of oil equivalent.[485] According to the UNECE, Uzbekistan's resource potential for green hydrogen production, based on its available resources and energy sources, ranges between 33,000 and 1,310,000 tons annually.[486]

Uzbekistan is actively pursuing a transition to a green economy and implementing reforms in its energy sector, including expanding the use of renewable

[476] United Nations Economic Commission For Europe (2023), *Low-carbon hydrogen production in the CIS countries and its role in the development of the hydrogen ecosystem and export potential.*
URL: https://unece.org/sites/default/files/2023 03/EN_Sustainable%20Hydrogen%20Production%20Pathways_final_0.pdf

[477] Индина М. (2022), *Кыргызстан может занять свою нишу в производстве водородной энергии.*
URL: https://www.akchabar.kg/ru/article/economy/kyrgyzstan-mozhet-zanyat-svoyu-nishu-v-proizvodstve-vodorodn/

[478] Central Asia News (2023), *Киргизия намерена расширить связи с ФРГ в сфере выработки «зелёного» водорода.*
URL: https://centralasia.news/22440-kirgizija-namerena-rasshirit-svjazi-s-frg-v-sfere-vyrabotki-zelenogo-vodoroda.html

[479] United Nations Economic Commission For Europe (2023), *Low-carbon hydrogen production in the CIS countries and its role in the development of the hydrogen ecosystem and export potential.*
URL: https://unece.org/sites/default/files/2023-03/EN_Sustainable%20Hydrogen%20Production%20Pathways_final_0.pdf

[480] Neftegaz (2023), *Таджикистан планирует ежегодно производить 1 млн т зеленого водорода для экспорта в страны ЦА.*
URL: https://neftegaz.ru/news/Alternative-energy/795709-tadzhikistan-planiruet-ezhegodno-proizvodit-1-mln-t-zelenogo-vodoroda-dlya-eksporta-v-strany-tsentra/

[481] CO_2 can be permanently stored in aquifers or old oil and gas reservoirs. See also: UNECE Technology Brief – Carbon Capture, Use and Storage (CCUS). URL: https://unece.org/sites/default/files/2021-03/CCUS%20brochure_EN_final.pdf

[482] Мельников Ю. (2022), *Низкоуглеродное производство водорода в странах СНГ и его роль в развитии водородной экосистемы и экспортного потенциала*, UNECE.
URL: https://unece.org/sites/default/files/2022-11/2022-11-14%20Almaty%20conference%20%28RUS%29.pdf

[483] United Nations Economic Commission For Europe (2023), *Low-carbon hydrogen production in the CIS countries and its role in the development of the hydrogen ecosystem and export potential*.
URL: https://unece.org/sites/default/files/2023-03/EN_Sustainable%20Hydrogen%20Production%20Pathways_final_0.pdf

[484] OSCE (2022), *Roadmap for the development of green hydrogen energy discussed at OSCE-organized roundtable in Turkmenistan.*
URL: https://www.osce.org/ru/centre-in-ashgabat/518067

[485] Energy Charter (2022), *IDEER: Uzbekistan 2022.*
URL: https://www.energycharter.org/fileadmin/DocumentsMedia/IDEER/IDEER-Uzbekistan_2022_ru.pdf

[486] United Nations Economic Commission For Europe (2023), *Low-carbon hydrogen production in the CIS countries and its role in the development of the hydrogen ecosystem and export potential.*
URL: https://unece.org/sites/default/files/2023-03/EN_Sustainable%20Hydrogen%20Production%20Pathways_final_0.pdf

energy sources and fostering the stable development of hydrogen energy.[487] As part of the "Roadmap for the Transition to Low-Carbon Energy" in the Uzbek electric power sector – developed with support from the EBRD and financing from Japan – plans include utilizing excess renewable energy production to support the growth of a hydrogen economy. [488]

In 2021, the National Research Institute of Renewable Energy was established, building upon the International Solar Energy Institute of the Academy of Sciences under the Ministry of Energy. Within its structure, the institute includes the Research Center for Hydrogen Energy and laboratories dedicated to testing and certifying renewable and hydrogen energy technologies.[489] The institute focuses on advancing priority areas such as expanding the use of renewable energy sources and promoting hydrogen energy. It also works on developing regulatory projects aligned with international standards. Furthermore, plans are underway to establish a Green Hydrogen Center with support from USAID. [490]

Other institutes in Uzbekistan are also conducting groundbreaking research in hydrogen energy. For instance, a team of scientists from the Institute of Material Sciences of the Academy of Sciences of the Republic of Uzbekistan, led by Dr. R. Rakhimov, has developed a new photocatalyst with the potential to revolutionize green hydrogen production. This innovative catalyst achieves record efficiency of up to 95% when using solar energy. The process leverages the pulsed tunneling effect, enabling precise adjustment of radiation pulse parameters to match the energy required for water decomposition. This approach significantly enhances energy efficiency. Remarkably, the catalyst operates at steam temperatures as low as 93-98°C, compared to traditional methods that necessitate heating water to 900°C.[491]

In 2022, the Ministries of Energy of Uzbekistan and Saudi Arabia, along with Saudi companies ACWA Power and Air Products, signed an agreement to advance research, development, and production of green hydrogen in Uzbekistan.[492] By 2023, in collaboration with ACWA Power, construction began on a pilot green hydrogen production facility. In the first phase, with financing from the EBRD,[493] the project aims to produce 3,000 tons of hydrogen annually. This hydrogen will be processed into mineral fertilizers using a 20 MW electrolyser installed in Chirchik, Tashkent region, and supported by a 52 MW wind power plant located at the existing Bash WPP in Gijduvan district, Bukhara region.[494] In the second phase, 2.4 GW of wind energy will be harnessed to enable the production of 500,000 tons of green ammonia annually.

Conclusion

Green hydrogen holds strategic importance for global decarbonization and achieving the UN Sustainable Development Goals (SDGs), particularly in providing clean, affordable energy and combating climate change. The development of a green hydrogen economy is being actively pursued by countries like Japan, China, India, South Korea, the United States, and EU nations, which are making significant investments and advancing technologies in this field. Key drivers behind the development of green hydrogen energy include the need for decarbonization, its potential for export, and its contribution to energy security. However, its adoption faces challenges such as high production costs, significant water requirements, the need for substantial infrastructure development, and the creation of a viable sales market.

The key prerequisites for green hydrogen production include: availability of land resources for installing renewable energy infrastructure, favorable climatic conditions to support the development of renewable energy potential, access to water sources for electrolysis and cooling processes, a developed industrial infrastructure to facilitate domestic consumption, particularly industries already using gray hydrogen and with potential demand for green hydrogen, and transport connectivity to enable efficient hydrogen exports.

Central Asian countries possess favorable conditions for the development of green hydrogen energy. Among them, Kazakhstan and Uzbekistan, which have the greatest production potential (see the

[487] Decree No.PP-4477 dated 04.10.2019 "On approval of the Strategy for the Transition of the Republic of Uzbekistan to a green economy for the period 2019-2030". Decree No.PP-436 dated 02.12.2022 "On measures to improve the effectiveness of reforms aimed at the transition of the Republic of Uzbekistan to a green economy by 2030"

[488] *A roadmap for the transition to low-carbon energy in the Uzbek electricity sector.* The document has not been officially approved. URL: https://minenergy.uz/uploads/0e7a9206-2afc-0897-d164-101e895a5d3c_media_.pdf

[489] Decree No.PP-5063 dated 04.09.2021 "On measures for the development of renewable and hydrogen energy in the Republic of Uzbekistan"

[490] U.S. Embassy in Uzbekistan (2024), *USAID energizes Uzbekistan's first green hydrogen hub.* URL: https://uz.usembassy.gov/ru/usaid-energizes-uzbekistans-first-green-hydrogen-hub-ru/

[491] Anhor.uz (2024), *Узбекские ученые разработали прорывную технологию получения зеленого водорода.* URL: https://anhor.uz/ekologiya/vodorod/

[492] Ministry of Energy of the Republic of Uzbekistan (2022), *Новый этап узбекско-саудовского энергетического сотрудничества.* URL: https://minenergy.uz/ru/news/view/2109

[493] The project is estimated at a total of $95.4 million, including a loan of $58.2 million

[494] Weekly.uz (2024), *В Узбекистане запускается пилотный проект «Зеленый водород».* URL: https://weekly.uz/articles/5874/

[495] RenEn (2023), *В Узбекистане начат проект по производству «зеленого» водорода.* URL: https://renen.ru/v-uzbekistane-nachat-proekt-po proizvodstvu-zelenogo-vodoroda/

table below),[496] are already taking initial steps to advance this sector.

The successful development of green hydrogen requires a comprehensive approach, including the creation of a robust regulatory framework, advancement of technologies, establishment of necessary infrastructure, reduction of production costs, expansion of local demand for green hydrogen in key industries, and active international cooperation.

Resource potential for green hydrogen production (generated from water electrolysis using renewable energy sources) in Central Asian countries by 2040, thousand tons per year

Country	Minimum scenario	Maximum scenario
Kazakhstan	85	1,464
Kyrgyz Republic*	5	145
Tajikistan	9	204
Turkmenistan	6	321
Uzbekistan	33	1,310

*) From small and large hydropower plants

Source: United Nations Economic Commission For Europe (2023), *Low-carbon hydrogen production in the CIS countries and its role in the development of the hydrogen ecosystem and export potential.*
URL: https://unece.org/sites/default/files/2023-03/EN_Sustainable%20Hydrogen%20Production%20Pathways_final_0.pdf

Development of sales markets. Currently, hydrogen exports from Central Asia face challenges due to the region's distance from key importers, such as the European Union, and the lack of direct access to the open sea. However, there is an opportunity to enter the Chinese market via a shared border, as well as potential access to the European market through cooperation with Russia and countries in the Caucasus. Export opportunities could also be expanded by leveraging the existing and promising gas transportation infrastructure.

Regional clusters. Experts suggest that, in the context of an actively developing renewable energy market across all Central Asian countries, regional cooperation will be a logical response to the growing competition in the export of green hydrogen. Such collaboration would allow for the most efficient use of existing infrastructure, optimizing it for green hydrogen exports, and enabling a greater utilization of renewable energy resources for its production.[497] Central Asian countries can maximize the benefits of cooperation in green hydrogen if they coordinate their efforts and develop regional production clusters.[498] This approach would also help diversify government revenues and reduce dependence on oil and gas exports. To achieve the most efficient production of green hydrogen and increase their share in the global market as exporters, these countries need to:

- promote the creation of a coordinated renewable energy development program among the countries in the region;
- develop a unified, transparent legislative framework to attract investments;
- adopt standardized technical requirements for green hydrogen infrastructure;
- establish joint training programs for new specialists, involving the private sector;
- create a regional distribution system for green hydrogen;
- upgrade power lines to ensure efficient transmission of electricity generated from renewable energy sources, thereby increasing the capacity for green hydrogen production.[499]

[496] Indina M. (2022), *Кыргызстан может занять свою нишу в производстве водородной энергии.*
URL: www.akchabar.kg/ru/article/economy/kyrgyzstan-mozhet-zanyat-svoyu-nishu-v-proizvodstve-vodorodn/
[497] Qazaq Green (2022), *Необходимость региональной кооперации для развития «зеленого» водорода в Центральной Азии.*
URL: https://qazaqgreen.com/journal-qazaqgreen/expert-opinion/187/
[498] *Development of the capacities of "green" hydrogen with the help ofThe formation of international clusters is already a popular strategy, for example in the European Union.* URL: https://qazaqgreen.com/journal-qazaqgreen/expert-opinion/187/
[499] Qazaq Green (2022), *Необходимость региональной кооперации для развития «зеленого» водорода в Центральной Азии.*
URL: https://qazaqgreen.com/journal-qazaqgreen/expert-opinion/187/

The development of green hydrogen in Central Asia requires careful consideration of the relationship between water and energy resources. In water-scarce regions, it is important to address the need for water in hydrogen production, as well as the potential impacts of constructing hydropower plants. One promising approach is to explore the use of hydrogen as an energy storage solution for regulating the flow of transboundary rivers in the Aral Sea basin. Specifically, it is proposed to convert excess hydropower in Kyrgyzstan and Tajikistan, during periods of high water flow, into hydrogen for storage and later use.[500]

To develop integrated, sustainable, and socially responsible green hydrogen projects, **it is recommended to utilize strategic environmental and social assessment** (SESA). This process evaluates the potential environmental and social consequences of green hydrogen policies, plans, or programs from a strategic perspective. The approach considers various types of infrastructure and incorporates environmental and social criteria for evaluating and licensing potential green hydrogen production projects and related facilities. Additionally, it is essential to develop appropriate measures to mitigate impacts and risks throughout the implementation of these policies, plans, or programs.[501]

[500] *Green Technologies for Eurasia's Sustainable Future*/Edited by Evgeny Vinokurov. Moscow: Eurasian Development Bank, Global Energy Association, 2021. URL: https://eabr.org/upload/iblock/d4f/EDB_-GLEN_2021_Report_Green-Technologies_eng.pdf

[501] Hurwitz Z., Bujak N., Tapia M., Daza E., Gischler Ch. (2023) *Key aspects for managing the environmental and social risks of green hydrogen.* Inter-American Development Bank.
URL: https://blogs.iadb.org/sostenibilidad/en/key-aspects-for-managing-the-environmental-and-social-risks-of-green-hydrogen/