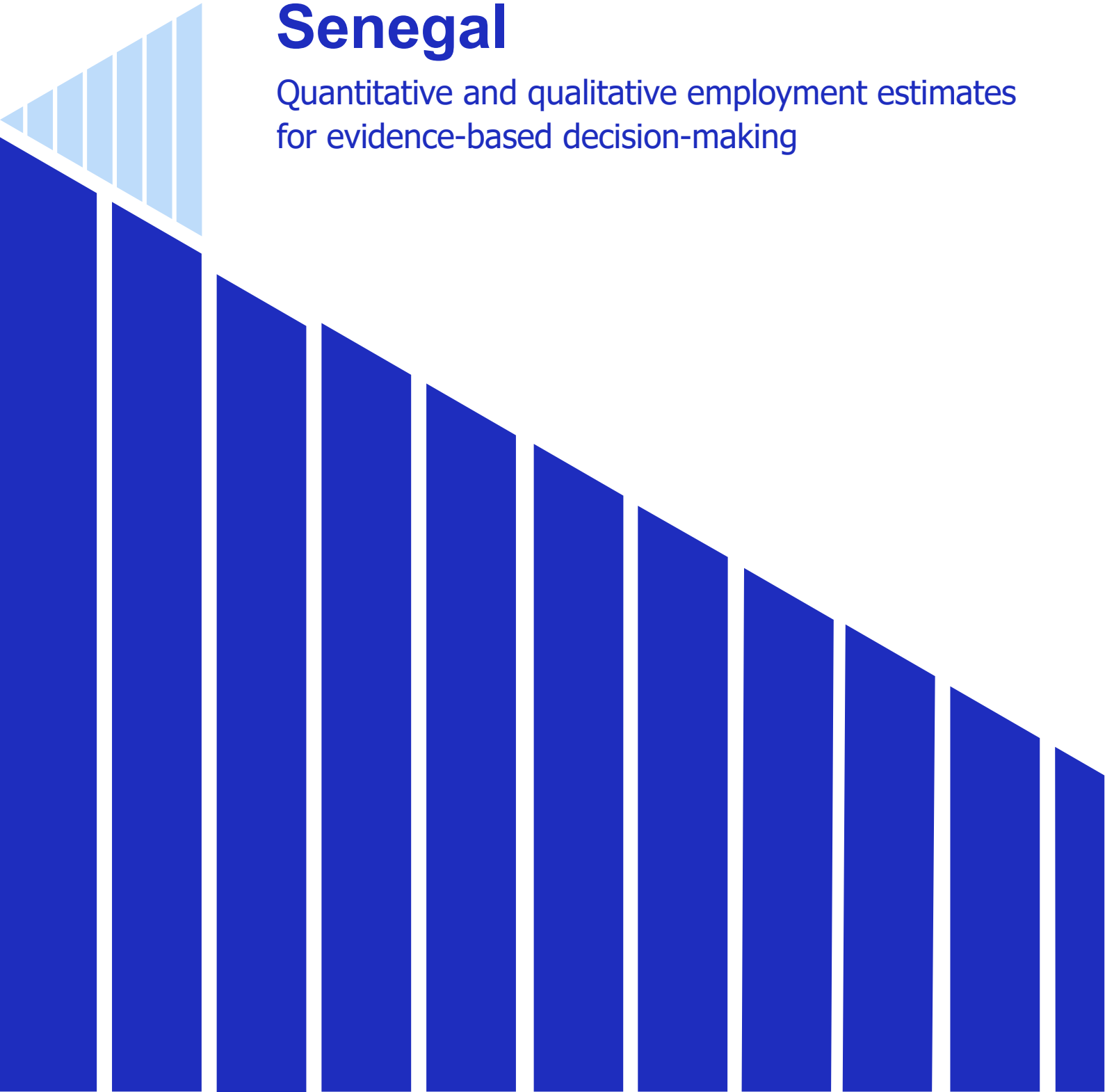
International Labour Organization

Impacts of heat stress on jobs and productivity in Senegal

Quantitative and qualitative employment estimates for evidence-based decision-making



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1. Background

In 2015, the ILO Guidelines for a just transition towards environmentally sustainable economies and societies for all were adopted. The preamble of the Paris Agreement on climate change, adopted in 2015, underscores close links between climate action, sustainable development and a just transition, with Parties to the Agreement "taking into account the imperatives of a just transition of the workforce and the creation of decent work and quality jobs in accordance with nationally defined development priorities". In 2023, the International Labour Conference adopted the Resolution concerning a just transition towards environmentally sustainable economies and societies for all, which endorsed the ILO Just Transition Guidelines as the central reference for policymaking and a basis for action. Ideally, any climate change policy process [such as the Nationally Determined Contributions (NDC), National Adaptation Plans (NAPs) or the Long-Term Low Emission Development Strategies (LT-LEDS)] should be informed by an assessment of the employment impacts—both positive and negative—as well as an indication of the measures that will be taken to ensure a just transition for workers and enterprises drawing on the ILO Just Transition Guidelines and the 2023 ILC Resolution. Against this backdrop, it is crucial to evaluate how environment and climate policies affect job creation or destruction (particularly for women and youth), income distribution, skills development, and overall economic growth. Providing quantitative and qualitative employment estimates for evidence-based decision-making is essential for maximizing positive and mitigating or buffering negative social and employment outcomes.

Heat stress, exacerbated by rising global temperatures and more frequent heatwaves, poses a significant challenge to occupational safety and health (OSH). According to a recent report published by the International Labour Organization (ILO),[1] excessive heat impacts more than 70% of the global workforce, exposing over 2.41 billion workers annually to hazardous conditions. The consequences are profound, with heat stress contributing to approximately 22.85 million non-fatal injuries and 18,970 fatalities every year across the world.[1] The economic and productivity costs are equally alarming, as heat stress leads to billions of productivity losses and healthcare costs annually.[1] These losses undermine economic stability and exacerbate inequalities in jobs and/or regions with high exposure to excessive heat.

1.1. Scope of this study

The available evidence underlines the urgent need to integrate heat stress mitigation strategies into national and workplace OSH frameworks. As a result of the ILO's work with the Climate Vulnerable Forum, the present study builds on the available data to provide just transition input to Climate Prosperity Plans (CPPs). It evaluates the implications of heat stress in Senegal's labour market and proposes evidence-based strategies to enhance worker safety and economic resilience. It also assesses employment data scenarios linked to green transitions and global warming, with a particular focus on productivity losses due to heat stress.

1.2. Political, economic, social, and climate overview

1.2.1. Governance and political stability

Senegal has a population of about 18 million[2] and owes its name to the Senegal River, which borders it to the east and north.[3] The capital and largest city is Dakar, while other significant cities include Touba, Thiès, and Rufisque.

[1] ILO (2024). Heat at work: Implications for safety and health. A global review of the science, policy and practice. A. D. Flouris, M. Azzi, H. Graczyk, B. Nafradi and N. Scott. Geneva, Switzerland, International Labour Organization.
[2] 2024 Revision of World Population Prospects. United Nations Department of Economic and Social Affairs, Population Division. https://population.un.org/wpp. Accessed: 18/12/2024.
[3] Holloway B. (2018). The Real Story Behind Senegal's Name. https://theculturetrip.com/africa/senegal/articles/the-real-story-behind-senegals-name. Accessed: 18/12/2024.

Senegal has remained one of Africa's most stable democracies over the past decade, with peaceful elections, a consolidated constitutional system, and relatively smooth transfers of power.[4,5] This evolving institutional landscape, alongside governance reforms and strengthened public services, has reinforced overall political stability, despite occasional unrest related to separatist tensions in the Casamance region and protests over political controversies.[6] Despite these challenges, regular elections and continued focus on anti-corruption and decentralization have supported Senegal's progress in maintaining democratic integrity and creating a foundation for further development initiatives.

Successive governments implemented policy initiatives to strengthen governance and public services. Reforms in 2013 updated citizenship laws to promote gender equality, allowing women to transmit citizenship on equal terms with men.[6] Decentralization efforts have continued to empower local governments, although administrative capacity remains stronger in urban centers than in remote areas.[6] The government also launched anti-corruption efforts that saw investigations of high-profile figures, albeit critics argued these were selective.[5,6] Overall, over the past decade Senegal has managed to uphold democratic institutions and stability, enabling it to focus on development policies and reforms.

1.2.2. Economic trends and performance

Senegal's economy has experienced robust growth over the past decade, consistently outpacing the regional average. Between 2014 and 2019, real GDP growth averaged approximately 6%, driven largely by the Plan Sénégal Émergent, an ambitious development strategy launched in 2014 which spurred public investments in infrastructure, energy, and agriculture.[7] Key infrastructure projects, including upgraded roads, a modernized airport, and a regional express train, coupled with an improved regulatory environment, bolstered investor confidence and fostered economic expansion. However, this growth did not sufficiently reduce poverty, partly because of persistent structural challenges and vulnerability to external shocks.

The COVID-19 pandemic abruptly halted progress in 2020, with real GDP growth contracting sharply from 5.3% in 2019 to 1.5% in 2020.[7] Sectors such as tourism, transport, and trade were particularly affected, leading to rising unemployment. A significant government relief package exceeding 2 billion USD helped cushion the economy, preventing a deeper recession and paving the way for a swift rebound of 6.5% growth in 2021.[8] Despite this recovery, growth decelerated to 4.2% in 2022, reflecting inflationary pressures from elevated global commodity prices and disruptions linked to the conflict in Ukraine, as well as adverse rainfall that hindered agricultural output.[8] Key economic trends include:

- **Macroeconomic and monetary conditions:** Historically low inflation gave way to higher prices in 2021-2022, driven by surging import costs for food and fuel. Annual inflation peaked at 9.7% in 2022, eroding household purchasing power.[9] In 2023, inflation moderated to around 5.9% following monetary tightening and easing global price pressures.[5] The Central Bank of West African States adjusted interest rates, and the government introduced caps on certain prices to address inflation. Projections indicate a return to the West African Economic and Monetary Union target range of 1-3% in 2024, contingent on continued external stabilization.[4,5]

[4] World Bank Group. 2024. Senegal Country Climate and Development Report. CCDR Series. Washington, DC: World Bank.
[5] World Bank (2024). The World Bank in Senegal. https://www.worldbank.org/en/country/senegal/overview. Accessed: 18/12/2024.
[6] Bertelsmann Stiftung (2024). BTI 2024 Country Report — Senegal. Gütersloh: Bertelsmann Stiftung. https://bti-project.org/en/reports/country-report/SEN. Accessed: 28/11/2024.
[7] Sylla F.N., Diagne A. (2024). Reallocations of special drawing rights and financing of the economic recovery in Senegal. AERC Working Paper SDR-004. African Economic Research Consortium. Nairobi, Kenya.
[8] Diallo A., Aminatou Ba H., Kouame W.A., Backiny-Yetna P.R., Valderrama Gonzalez D., Gallegos Vargas G.A. (2024). Senegal Economic Update: Seizing the Opportunity. Washington, D.C.: World Bank Group.
[9] MacroTrends (2025). Senegal Inflation Rate 1968-2025. https://www.macrotrends.net/global-metrics/countries/sen/senegal/inflation-rate-cpi. Accessed: 18/12/2024.

- **Fiscal policy and public debt:** Public spending has remained expansionary due to crisis-response measures and subsidies during the commodity price shock of 2022.[4] These interventions, alongside borrowing for prospective oil and gas projects, pushed public debt from the mid-50% range of GDP in 2015 to around 75% of GDP in 2022, slightly above the West African Economic and Monetary Union convergence criterion of 70%.[10] While Senegal's debt remains at moderate risk, authorities plan to narrow the fiscal deficit to 3% of GDP by 2025, supported by revenue increases expected from hydrocarbon projects.[10] Containing debt will require fiscal discipline as well as strong growth to increase the revenue base.

- **Structural reforms and outlook:** Under the Plan for Emerging Senegal, the government prioritized structural transformation to enhance competitiveness and diversify the economy.[11] Investments in power generation reduced electricity outages, while Special Economic Zones attracted investment in manufacturing industries such as textiles and automotive assembly.[12] Reforms in business registration, port efficiency, and digital service delivery facilitated an improved business environment, and Senegal's participation in the G20 Compact with Africa further aimed to attract private capital.[13] Nonetheless, vulnerabilities remain, including a predominantly informal labour market (around 85% of employment) and reliance on rain-fed agriculture.[5]

1.2.3. Social development and challenges

Senegal has made progress in human development over the last decade but still grapples with poverty and inequality issues. Key social indicators and challenges include:

- **Poverty and Inequality:** Senegal achieved modest improvements in reducing poverty throughout the 2010s, with the national poverty rate declining from approximately 43% in 2011 to 37.8% in 2018.[14] Despite a period of strong economic expansion, these gains have been uneven, leaving rural areas especially vulnerable, with 54% of the population living in poverty.[14] While urban poverty stands at around 20%, marked inequalities persist in fast-growing urban centers, reflecting limited impact of growth on the poorest.[15] Moreover, the Gini index remains around 40, indicating that income inequality has not declined significantly.[4] Nearly 55% of households are considered economically vulnerable and risk falling below the poverty line if confronted by shocks, underscoring the need for broader and more inclusive economic opportunities.[4]

- **Impact of COVID-19 on Poverty:** The COVID-19 pandemic in 2020 reversed part of the decade's poverty reduction progress. Poverty levels rose by an estimated 2 percentage points (equivalent to about 350,000 people) due to job and income losses during lockdowns.[14] Urban areas experienced a notable increase of 2.7 percentage points in poverty, reflecting the disproportionate impact on informal workers

[10] World Bank (2023). Senegal Economic Update 2023: Addressing the needs of vulnerable groups for national development. Washington, DC: World Bank. https://www.worldbank.org/en/country/senegal/publication/senegal-economic-update-2023-addressing-the-needs-of-vulnerable-groups-for-national-development. Accessed: 18/12/2024.
[11] United Cities and Local Governments (2022). Country-by-country analysis of SDG localization: Senegal. Barcelona, Spain.
[12] Bailey H. (2020). 2020 Investment Climate Statements: Senegal. U.S. Department of State. Dakar, Senegal. https://www.state.gov/reports/2020-investment-climate-statements/senegal. Accessed: 18/12/2024.
[13] German Federal Ministry for Economic Cooperation and Development (2024). Senegal - Strong role of small-scale enterprises. https://www.bmz.de/en/countries/senegal. Accessed: 18/12/2024.
[14] Backiny-Yetna P.R. (2021). Poverty & Equity Brief - Africa Western & Central: Senegal. Washington, DC: World Bank.
[15] Food and Agriculture Organization of the United Nations (2024). Senegal: Scaling up Climate Ambition on Land Use and Agriculture through Nationally Determined Contributions and National Adaptation Plans (SCALA). https://www.fao.org/in-action/scala/countries/senegal/en. Accessed: 18/12/2024.

and small enterprises.[14] Household surveys conducted in late 2020 indicated widespread difficulties, with 66% reporting income losses and 54% experiencing food insecurity.[14]

- **Employment and Labour Market:** Despite robust economic growth, formal job creation has lagged behind the rapidly expanding labour force, contributing to an unemployment rate of about 15%, particularly acute among urban youth.[16] Agriculture remains the largest source of employment, with around 70% of households engaging in farming or livestock, though it contributes less than 20% of GDP.[16] Recent investments under the Plan for Emerging Senegal have generated new opportunities in construction, transport, and manufacturing, supported by youth- and women-focused credit and entrepreneurship programs.[16] However, structural constraints persist, including a limited formal sector and gaps between education outcomes and labour market needs. Senegal's Human Capital Index, at 0.42, underscores the importance of enhancing education and vocational training for improved employment prospects.[16]

- **Social Protection Measures:** Over the past decade, the government, with support from international partners, has expanded social protection initiatives, notably through the National Family Security Grants Program.[16] As of mid-decade, this program had reached approximately 300,000 poor households, and these efforts have been supported by the development of a national social registry, now covering over 540,000 households.[16] Adaptive social protection initiatives, such as the Yokk Koom Koom program and the Agricultural Resilience Program, aim to build resilience against shocks by providing job training, farming inputs, and cash grants.[16] While social safety nets have helped mitigate the impact of crises (e.g., COVID-19 and food price spikes), total social protection spending remains at about 3% of GDP, leaving many vulnerable populations uncovered.[17]

- **Food Security:** Food security remains a persistent concern, given Senegal's reliance on cereal imports (particularly rice) to meet approximately 60% of domestic demand.[4,18] Erratic rainfall, land degradation, and limited mechanization constrain agricultural output, exacerbating seasonal food shortages and vulnerability to shocks such as drought.[4,18] These factors, combined with elevated food prices during recent crises, contributed to heightened food insecurity for more than half of households in late 2020.[14] Government strategies to safeguard consumption include subsidies on essential commodities, emergency food distributions, and targeted export restrictions.[4] While nutrition indicators have shown gradual improvement, sustained progress requires further investments in irrigation, climate-smart agriculture, and expanded safety net coverage.[4]

- **Climate-Related Social Impacts:** Climate shocks (including heatwaves, droughts, floods, and locust invasions) undermine socioeconomic gains and heighten vulnerability for rural populations reliant on rain-fed agriculture.[4,16] Poor harvests and livestock losses disrupt incomes and food supply, often triggering localized food insecurity and migration.[4,16] Flooding poses additional risks in both rural flood-prone zones and urban settlements, affecting health, schooling, and livelihoods.[4,16] As climate variability intensifies, effective adaptation and risk management measures will be essential to protect social progress and support Senegal's most vulnerable communities.[4,16]

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[16] World Bank (2024). Sahel Adaptive Social Protection Program: Senegal. https://www.worldbank.org/en/programs/sahel-adaptive-social-protection-program-trust-fund/country-work/senegal. Accessed: 18/12/2024.
[17] Rougeaux S. (2017). Republic of Senegal - Social Protection public expenditure review 2010-2015: Summary and key recommendations. World Bank. Washington: D.C.
[18] World Bank (2011). Senegal Vulnerability, Risk Reduction, and Adaptation to Climate Change. World Bank. Washington: D.C.

1.2.4. Climate-related vulnerabilities and adaptation

Senegal faces increasing climate risks, with warming temperatures and growing variability in rainfall exerting pressure on key economic sectors such as agriculture and fisheries. These trends pose serious implications for livelihoods, food security, and macroeconomic stability. Projected climate scenarios indicate further temperature increases and shifts in precipitation, underscoring the urgency of adaptation measures. Key climate-related challenges and responses include:

- **Rising Temperatures and Heat Stress:** Annual mean temperatures have increased by approximately 0.9°C since 1960, contributing to more frequent extreme heat events, especially in inland areas.[18] Current projections suggest that much of Africa, including Senegal, could surpass 2°C of warming by the end of the century even under moderate scenarios.[19]

- **Changing Rainfall Patterns:** Senegal's single rainy season, historically occurring between June and September (extending to October in southern regions), is becoming more erratic.[19] While the north and center have seen slight declines in average rainfall, the far south occasionally experiences intense rain leading to flash floods. Urban areas, especially Dakar, are increasingly vulnerable to flooding because of heavy rainfall events combined with inadequate drainage infrastructure.[19] Climate models project both more frequent droughts and heightened rainfall extremes in the western Sahel.[19] Farmers, reliant on timely and predictable rains, face greater uncertainty regarding planting schedules, contributing to reduced yields and undermining rural livelihoods.[19]

- **Agriculture and Food Security:** As Senegal's agriculture is predominantly rain-fed, shifting weather patterns directly affect food production and rural incomes. Staple crops such as maize, sorghum, and millet are already experiencing declining yields due to shorter growing seasons, more frequent droughts, and higher heat stress.[4] Studies indicate maize yields in central regions could drop by about 15% by the 2050s under high warming scenarios and lack of effective adaptation.[18] Livestock productivity is similarly threatened, as drought reduces forage availability and contributes to herd losses.[4] These impacts on crops and livestock exacerbate food insecurity, with climate shocks identified as a key driver of recent Sahel-wide food crises.[16] Without adaptation, projections suggest an additional two million Senegalese could fall into poverty by 2050.[4]

- **Coastal Zones and Sea-Level Rise:** Senegal's 700 km Atlantic coastline is at heightened risk from sea-level rise (measured at 3-5 mm per year), coastal erosion, and potential storm surges.[19] Currently, 56% of the coastline is eroding, with Saint-Louis among the most affected urban centers: by 2080, up to 80% of the city could face periodic flooding, potentially displacing 150,000 residents.[19,20] The government has already undertaken emergency relocations to protect vulnerable communities, and Dakar's infrastructure (e.g., the Corniche road) remains susceptible to wave action and inundation.[21] Furthermore, saltwater intrusion affects rice production in river delta areas, while warmer ocean temperatures and shifting currents threaten coastal fisheries and marine biodiversity. Without significant adaptation, annual economic losses from climate impacts could reach 3-4% of GDP by 2030 and rise to 9.4% by 2050.[4]

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[19] UNFCCC (2020). Climate Change Is an Increasing Threat to Africa. United Nations Framework Convention on Climate Change. Bonn, Germany. https://unfccc.int/news/climate-change-is-an-increasing-threat-to-africa. Accessed: 18/12/2024.
[20] Pronczuk M. (2020). How the 'Venice of Africa' is losing its battle against the rising ocean. The Guardian. https://www.theguardian.com/environment/2020/jan/28/how-the-venice-of-africa-is-losing-its-battle-against-the-rising-ocean. Accessed: 18/12/2024.
[21] Ba S., Alioune Djigo S. (2024). Strengthening coastal resilience in Senegal: a vital issue for the people of Saint-Louis. Prevention Web: United Nations Disaster Risk Reduction. https://www.preventionweb.net/news/strengthening-coastal-resilience-senegal-vital-issue-people-saint-louis. Accessed: 18/12/2024.

In summary, climate change poses a multifaceted challenge to Senegal's development trajectory, affecting key sectors and intensifying vulnerability for rural and urban populations. Strengthening climate resilience will require a comprehensive policy response, including addressing the impacts of workplace heat stress, targeted investments in climate-smart agriculture, improved water and coastal management, and bolstered social protection systems. Timely and coordinated adaptation efforts can help safeguard recent development gains and foster more sustainable, inclusive growth.

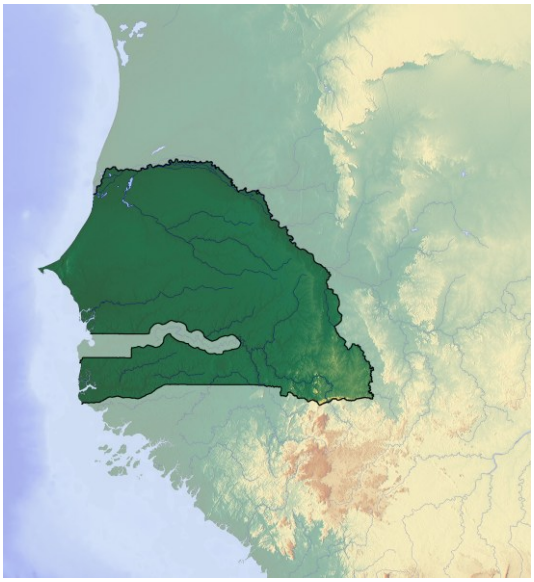
2. Current and future heat exposure and climate change

2.1. Current weather and climate overview

Senegal is positioned at the western tip of West Africa along the Atlantic coast, bordered by Mauritania to the north, Mali to the east, Guinea to the southeast, and Guinea-Bissau to the southwest (Figure 1). Senegal nearly encircles The Gambia, a country that occupies a narrow corridor around the Gambia River and separates Senegal's southern region of Casamance from the rest of the nation.

Senegal's climate is generally classified as tropical semi-arid, with a clear division between a short rainy season and a prolonged dry season.[18] The country experiences one main wet season from June to September, peaking in August, when the West African monsoon brings virtually all of the annual rainfall.[18] From October to May, conditions are typically dry, influenced by the hot Harmattan winds.[18] Rainfall amounts increase markedly from north to south: the arid northern Sahelian zone often receives under 300 mm of rain per year, whereas the southern regions along the Guinea border receive 1000-1200 mm annually.[18] Rainfall patterns are highly variable from year to year and even decade to decade. Temperatures in Senegal are consistently high year-round. Historically, the national mean annual temperature is around 27-28°C, with the hottest months (at the end of the dry season) averaging daily highs in the mid-30°C.[18] Coastal areas tend to be slightly moderated by the Atlantic Ocean, while interior regions experience more extreme heat.[18] Overall, the climate is characterized by intense seasonality – a brief, intense rainy period and a long, dry spell – and significant spatial variability in rainfall.

Figure 1. Senegal physical map.[22]



2.1.1. Recent climate trends and variability

Over the past few decades, Senegal has witnessed noticeable shifts in its climate. From the 1960s through the 1980s, the country (like much of the Sahel) experienced a marked drying trend with persistent rainfall deficits and severe droughts.[23] Annual rainfall declined sharply during that period, contributing to the infamous Sahel droughts of the 1970s and 1980s.[23] This prolonged drought era was followed by a partial recovery of rainfall starting in the 1990s. Rainfall totals in the 2000s improved compared to the drought peak, but have not fully returned to the higher levels observed in the 1950s and early 1960s.[23] Importantly, rainfall remains highly unpredictable, as inter-annual variability is large and the country experiences alternations between wetter and drier years.[24] Meanwhile, temperatures have been rising. Analyses by Senegal's ecological monitoring center indicate that the country's mean annual temperature has increased by about 1.5-1.6°C since 1950.[24] This warming is slightly more pronounced in the interior northern regions (up to ~3°C increase) compared to the coast.[24] The overall result is that today's climate is hotter and, in terms of rainfall, still somewhat drier on average than mid-20th century conditions, although not as extremely dry as during the peak drought decades.

In the past 10 years, climate variability has been very evident across Senegal. Year-to-year rainfall has fluctuated significantly. Some years have been drier than average, leading to drought conditions, while others have seen above-average rainfall with flooding. Notably, the country endured severe droughts in 2011 and 2014, which

[22] The map was made using http://www.maps-for-free.com

[23] U.S. Geological Survey (2012). A Climate Trend Analysis of Senegal. U.S. Department of the Interior.

[24] CIAT, BFS/USAID (2016) Climate-smart agriculture in Senegal. CSA Country Profiles for Africa Series. International Center for Tropical Agriculture. Bureau for Food Security, United States Agency for International Development. Washington, D.C.

severely affected crop production and water availability.[4,25] By contrast, several recent rainy seasons have been exceptionally wet. For instance, 2020 brought heavy rains that far exceeded normal levels in many areas.[26] Overall, the 2010s were among the warmest decades on record in Senegal, consistent with global warming trends.[4] Many recent years have registered higher than normal temperatures, and the timing and intensity of rains have been somewhat unpredictable, occasionally deviating from long-term patterns.[4]

2.1.2. Extreme weather events in recent years

Senegal has experienced a number of extreme weather events in recent times, underlining the country's climate variability. Key events over the last decade include:

- **Heatwaves:** Episodes of extreme heat have affected Senegal, reflecting the rising temperature trend. The northern Sahelian zone, in particular, has seen intense heatwaves. In late May 2013, an exceptional heatwave hit northern Senegal with daytime temperatures soaring above 45°C for several consecutive days.[27] This event led to increased prevalence of heat-related illnesses and fatalities in the hardest-hit areas.[27] Other years have also recorded record-breaking heat. For instance, 2016 and 2018 both saw extreme hot spells with temperatures in the mid-40s°C in parts of the country.[27] These conditions have posed health risks, especially for vulnerable populations without access to cooling or adequate water and have stressed livestock as well.[27]

- **Droughts:** Periodic rainfall failures have led to serious droughts. In 2011, a major drought left an estimated 800,000 people facing food insecurity.[24] This was followed by another severe nationwide drought in 2014, and again in 2018, with 2018 noted as "the third severe drought in six years" (after 2011 and 2014).[25] These dry spells caused poor harvests, water shortages, and heightened food insecurity in many rural communities.

- **Floods:** Intensified heavy rainfall events have increasingly resulted in floods, especially in low-lying urban areas. Since the mid-2000s, seasonal flooding has become a recurring problem during the late summer rains.[28] For instance, in September 2020 torrential downpours in parts of Dakar and Thiès delivered roughly 800 mm of rain within a short period, flooding neighborhoods and disrupting livelihoods.[26] Similarly, in August 2022, Dakar experienced extreme rain with 84 mm of rain within 2 hours – an amount well above the threshold for "extreme" rainfall as defined by the national meteorological agency – resulting in severe urban flooding.[29] Such flood events have repeatedly caused damage to homes and infrastructure in recent years.

In summary, Senegal's climate over the past decade can be characterized by overall hotter conditions, a rainfall regime that oscillates between extremes of drought and intense rain, and a heightened incidence of extreme weather events. This climate profile, a hot semi-arid environment with high variability, has made the country particularly vulnerable to shocks such as prolonged dry spells, flash floods, and heatwaves. Each of these

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[25] Gray J., Allen M., Esser A., Borros G., Abrahams M., de Waal J., Mungai K., Pérez-Bobadilla V., Hougaard C. (2021). Unlocking the digital economy in Senegal. CENFRI. Tygervalley, South Africa.
[26] ReliefWeb (2020). Senegal: Floods - Sep 2020. United Nations Office for the Coordination of Humanitarian Affairs. https://reliefweb.int/disaster/fl-2020-000198-sen. Accessed: 18/12/2024.
[27] Sy I., Cissé B., Ndao B., Touré M., Diouf A.A., Sarr M.A., Ndiaye O., Ndiaye Y., Badiane D., Lalou R., Janicot S., Ndione J.A. (2022). Heat waves and health risks in the northern part of Senegal: analysing the distribution of temperature-related diseases and associated risk factors. Environmental Science and Pollution Research; 29(55): 83365-83377.
[28] The International Charter: Space and Major Disasters (2013). Flood in Senegal. https://disasterscharter.org/activations/flood-in-seneg-1. Accessed: 18/12/2024.
[29] Ngouda D. Diadie B. (2022). Senegal capital wades through floodwater after heavy rain. Thompson Reuters Foundation. https://www.reuters.com/world/africa/senegal-capital-wades-through-floodwater-after-heavy-rain-2022-07-20. Accessed: 18/12/2024.

hazards has impacted Senegal in the past decade, underscoring the importance of resilience measures in the face of current climate variability. The observed trends and events described above pertain to historical and present climate conditions in Senegal, providing context for understanding the nation's ongoing climate challenges.

2.2. Choice of environmental indicators

To characterize the prevailing environmental conditions for work in Senegal, the present study used two key indicators: the monthly average maximum temperature and the monthly average maximum Wet-Bulb Globe Temperature (WBGT). The rationale for selecting these indicators and the specific time constant is provided below:

Air temperature: Temperature is the standard metric used by weather and climate experts when referring to general atmospheric conditions. However, the working environment is more complex, as it often involves additional factors such as high humidity, low wind, and exposure to thermal radiation from the sun or machinery. Consequently, air temperature alone does not fully capture the thermal stress experienced by workers.[30]

Wet-Bulb Globe Temperature (WBGT): The WBGT is the most widely adopted indicator by scientists and occupational health and safety professionals to assess heat stress in the workplace and its effects on health and productivity.[30,31,32,33] Unlike air temperature, the WBGT integrates several factors – air temperature, humidity, wind speed, and thermal radiation – to provide a more comprehensive measure of the heat load experienced by the human body. Importantly, WBGT-based guidance takes into account work intensity and the use of personal protective equipment, making it especially useful for evaluating the risk of heat-related illnesses in occupational settings.

A recent series of large-scale multi-country evaluations of all the available indicators found that the WBGT is the most effective for evaluating the risk of heat-related illnesses for people who work in the heat.[30,34,35,36] A recent ILO analysis of legislation from countries across the world found that the WBGT is the most widely-used indicator of heat stress in the workplace.[1] Due to its strengths, the WBGT has been recommended by a number of national and international organizations for assessing heat stress including the ILO, the World Health Organization, and the World Meteorological Organization.[1,37] Detailed information regarding the methods used to estimate WBGT can be found in Annex 1.

Health and physical impacts of rising WBGT: As WBGT values increase, the human body experiences greater difficulty in dissipating heat, which can lead to a range of adverse effects. Elevated WBGT levels can cause:

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[30] Ioannou L.G., Tsoutsoubi L., Mantzios K., et al. (2022). Indicators to assess physiological heat strain - Part 3: Multi-country field evaluation and consensus recommendations. Temperature; 9(3): 274-291.
[31] NIOSH, Criteria for a recommended standard: occupational exposure to heat and hot environments, B. Jacklitsch, et al., Editors. 2016, Centers for Disease Control and Prevention. National Institute for Occupational Safety and Health. U.S. Department of Health and Human Services: Cincinnati, OH, USA.
[32] ISO, ISO 7243:2017 — Ergonomics of the thermal environment - Assessment of heat stress using the WBGT (wet bulb globe temperature) index. 2017, International Organization for Standardization: Geneva, Switzerland.
[33] ACGIH, Heat stress, TLVs and BEIs: threshold limit values for chemical substances and physical agents & biological exposure indices, ACGIH, Editor. 2020, ACGIH: Cincinnati.
[34] Ioannou L.G., Mantzios K., Tsoutsoubi L., et al. (2022). Indicators to assess physiological heat strain - Part 1: Systematic review. Temperature; 9(3): 227-262.
[35] Ioannou L.G., Dinas P.C., Notley S.R., et al. (2022). Indicators to assess physiological heat strain - Part 2: Delphi exercise. Temperature; 9(3): 263-273.
[36] Flouris A.D., Ioannou L.G., Nybo L. (2022). Working in a warming world: Translating thermal physiology to policy-relevant information. Temperature; 9(3): 223-226.
[37] World Health Organization and World Meteorological Organization (2025). Climate change and workplace heat stress: technical report and guidance. Geneva, Switzerland.

- **Reduced physical performance:** Increased heat stress slows down movement and reduces overall work capacity, as the body prioritizes cooling over physical exertion.[38]
- **Cardiovascular strain:** The heart works harder to pump blood to the skin for cooling, which can lead to increased heart rate and long-term cardiovascular stress.[39]
- **Fatigue and cognitive impairment:** Higher WBGT levels are associated with quicker onset of fatigue and reduced cognitive function, impacting decision-making and coordination.[1,40,41]
- **Heat-related illnesses:** Prolonged exposure can result in dehydration, heat cramps, heat exhaustion, or even heat stroke, especially in high-intensity work environments.[1,39] Working in a hot environment for a significant part of the year can lead to acute/chronic kidney injury.[1,39]

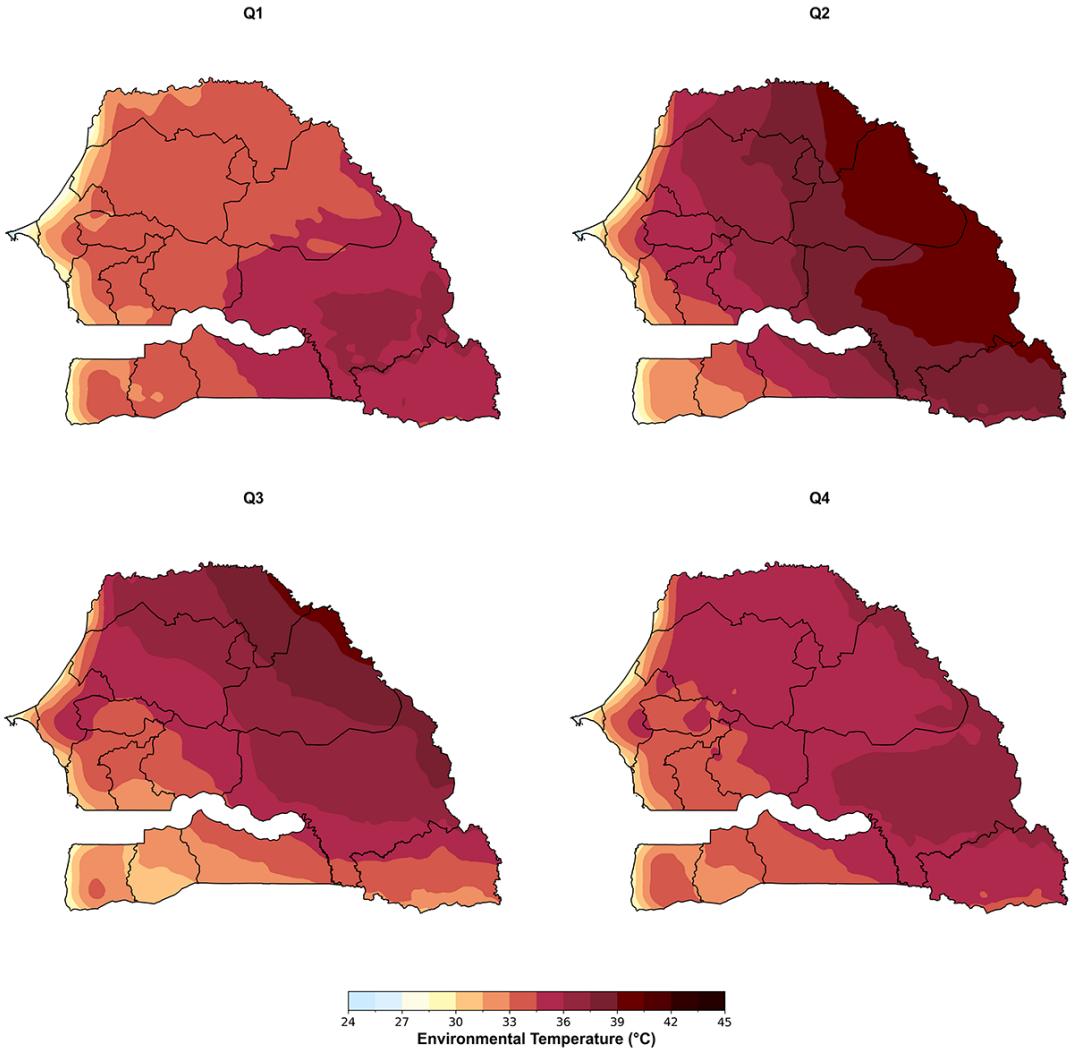
Choice of time constant: The analysis employs the monthly average maximum values for both temperature and WBGT because these values are typically observed between 12:00 and 14:00 – the period when most workers are active. This approach ensures that the indicators accurately represent the most challenging conditions encountered during the workday.

[38] Ioannou L.G., Foster J., Morris N.B., et al. (2022). Occupational heat strain in outdoor workers: A comprehensive review and meta-analysis. Temperature; 9(1): 67-102.
[39] Flouris A.D., Dinas P.C., Ioannou L.G., Nybo L., Havenith G., Kenny G.P., Kjellstrom T. (2018). Workers' health and productivity under occupational heat strain: a systematic review and meta-analysis. Lancet Planetary Health; 2(12): e521-e531.
[40] Flouris A.D. (2019). Human thermoregulation. in: Périard J., Racinais S., eds. Heat stress in sport and exercise: Springer.
[41] Flouris AD, Schlader ZJ. (2015). Human behavioral thermoregulation during exercise in the heat. Scandinavian Journal of Medicine and Science in Sports; 25 (S1): 52-64.

2.3. Current heat and environmental conditions

Figure 2 illustrates the quarterly average maximum environmental temperatures across Senegal. The maps show that Senegal's heat climate is defined by a strong ocean-to-interior gradient and a sharp spring peak. Inland districts, especially in the east and northeast, experience the most persistent and extreme heat. Coastal areas are consistently cooler but still require heat-based management because of humidity. An analysis of the maps indicates the following:

Figure 2. Quarterly average maximum environmental temperature across Senegal during the reference historical period (1985-2014).



Seasonality

- **Q1 (Jan-Mar):** The interior is already very hot. Large parts of the east and southeast experience 36-41°C, while the Atlantic strip from Dakar southward is markedly cooler at roughly 27-33°C.
- **Q2 (Apr-Jun):** This is the peak heat season. Much of the centre, east and northeast reaches 40-45°C, with the highest values clustered in the upper Senegal River valley and the southeast. Only a narrow coastal belt remains near 27-33°C; the Casamance coast is usually 33-36°C.
- **Q3 (Jul-Sep):** Temperatures moderate with the rains, most noticeably in the south and along the coast (30-36°C). The far north and northeast remain hot, often 39-43°C, so relief is uneven.

- **Q4 (Oct-Dec):** Heat rebuilds inland. Much of the interior returns to 38-42°C, while the coast remains relatively lower at 30-34°C.

Spatial patterns

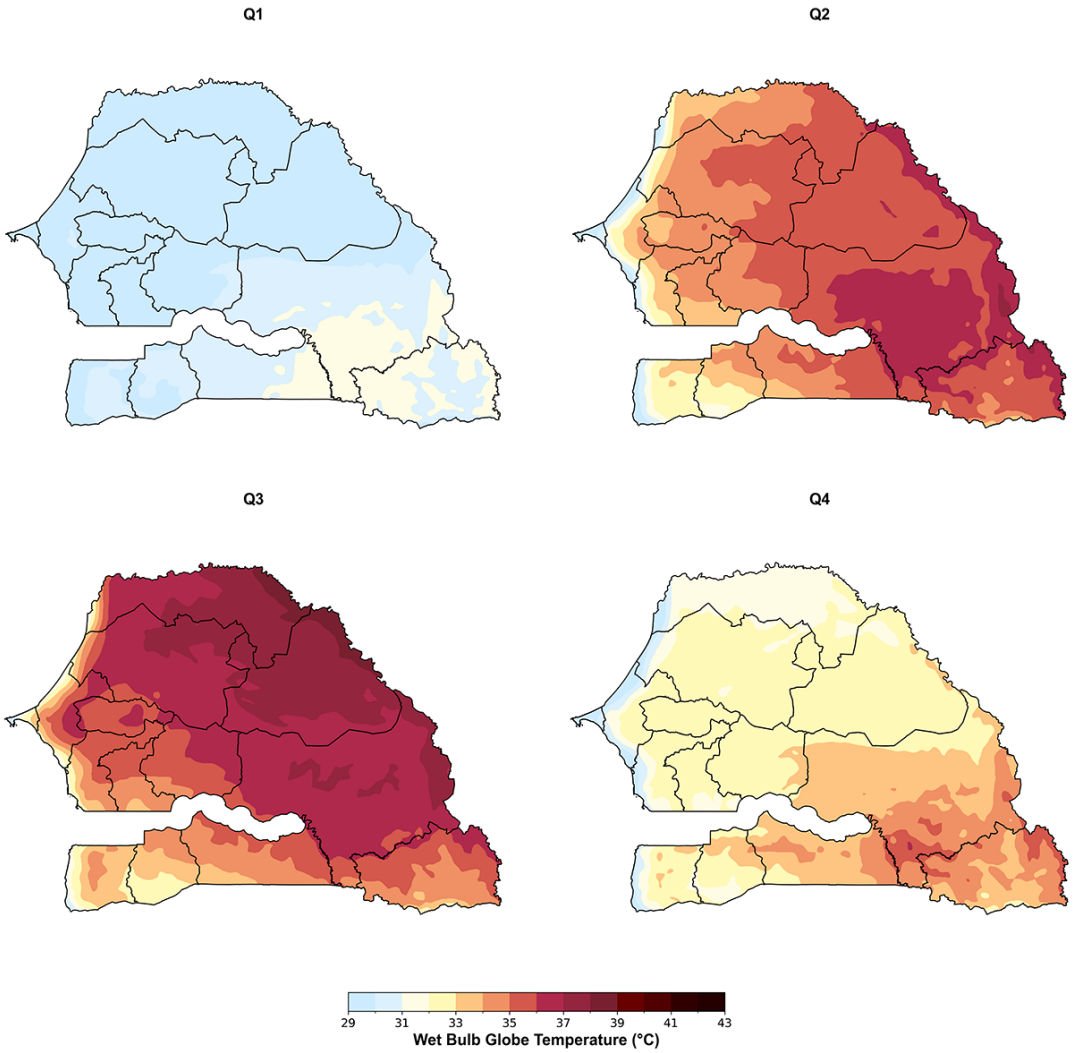
- A persistent coast-to-interior gradient dominates all quarters. The Atlantic transitional area between dry land and open water around Dakar, Thiès, and Saint-Louis is consistently cooler than inland districts.
- The hottest core lies in the eastern and northeastern interior (Tambacounda-Kédougou-Matam axis), which reaches the highest values in Q2 and remains very warm in Q3-Q4.
- The Casamance is warm but less extreme than the northeast, especially in Q3 when rain and cloud bring some moderation.
- River and valley corridors show slightly warmer passages extending westward from the interior toward central Senegal.

Implications for labour and OSH planning

- **Highest-risk window:** Q2 brings widespread inland maxima above 40°C. Outdoor and heavy work in the centre, east and northeast require sustained protections during this period.
- **Persistent hotspots:** The northeast remains hot into Q3, despite national rainfall. Worksites there need sustained protections through the wet season.
- **Coastal advantage with a caveat:** The Dakar-Petite Côte-Casamance coast is several degrees cooler across the year, offering better scheduling windows.
- **Planning by quarter:** Use Q1 mornings and Q3 on the coast and in the south for the most heat-exposed tasks. Prepare Q4 re-heat plans for the interior as temperatures climb again.

Figure 3 illustrates the quarterly average maximum WBGT across Senegal. WBGT is an important measure of heat stress, taking into account not only temperature but also humidity, wind speed, and solar radiation, which makes it particularly useful in assessing the risk of heat stress for working people. A close inspection of the maps provides the following observations:

Figure 3. Quarterly average maximum WBGT across Senegal during the reference historical period (1985-2014).



Seasonality

- **Q1 (Jan-Mar):** Heat stress is moderate over most of the country. WBGT sits mainly around 29-31°C, lowest along the Atlantic coast and in the lower Senegal-Gambia river plains. Patches in the far south nudge above 31°C.
- **Q2 (Apr-Jun):** Heat stress rises sharply. The east and southeast (Tambacounda-Kédougou belt) move into 35-39°C WBGT, while the centre and south are mostly 33-37°C. The narrow Atlantic fringe remains relatively cooler, typically 31-33°C.
- **Q3 (Jul-Sep):** This is the peak stress season. Much of the interior shows 37-41°C WBGT, with the highest values in the eastern highlands and the north-central interior. The coast is still relatively cooler but often above 33°C.

- **Q4 (Oct-Dec):** Partial relief. Large areas in the north and west fall back to 31-33°C, but the southeast and parts of Casamance often remain in the 33-37°C range.

Spatial patterns

- A persistent west-east gradient: the Atlantic coast (Dakar-Thiès-Saint Louis corridor) is the least heat-stressed in every quarter; inland and southeastern regions are the most exposed.
- Hotspots recur in Tambacounda and Kédougou, and along interior river valleys where humidity, low wind, and radiation combine. Casamance is cooler than the far east but still experiences high WBGT in Q2-Q3.
- Urban centres in the interior (e.g., Tambacounda, Kaolack, Ziguinchor's hinterland, and Kédougou) face compounded risk from urban heat and low ventilation during midday.

Implications for labour and OSH planning

- **Prioritise WBGT – not air temperature – for decisions:** When WBGT exceeds ~32-33 °C, enforce protection strategies such as water-rest-shade and slower work pace. At higher levels, continuous heavy work becomes unsafe.
- **Highest-risk window:** Q2-Q3 in the east and southeast where WBGT commonly sits between 35 and 41°C. Outdoor and high-exertion jobs (rain-fed agriculture, construction, road works, small-scale mining, cross-border logistics) require early-start schedules, longer and more frequent breaks, shaded/ventilated rest areas, and reliable hydration.
- **Safer scheduling window:** Q1 and Q4 along the coast and northern plains, when WBGT is typically 29-33 °C. These periods are preferable for peak-effort tasks, though midday exposure should still be limited.
- **Geographic targeting:** Scale protections first in Tambacounda-Kédougou and interior areas, then extend to Casamance and central regions. Maintain WBGT monitoring in Dakar and other coastal cities; while cooler than inland, WBGT frequently crosses 31-33 °C, warranting work-rest guidance for outdoor crews and poorly ventilated indoor sites.
- **Sector focus:** Agriculture and construction are most exposed; mining in Kédougou, transport hubs in Tambacounda/Kaolack, and informal urban services in inland towns also need dedicated protocols, training, and first-aid readiness.

Overall, Senegal's coastal belt enjoys a relative buffer, but Q2-Q3 bring widespread, extreme WBGT across the interior, with the southeast as the persistent hotspot. Heat-risk management should follow these seasonal and spatial patterns.

2.3.1. Findings from comparing temperature against WBGT

When comparing the maps showing environmental temperature against those illustrating the WBGT, the following key insights emerge:

Shared trends across both indicators

- **Seasonal peak:** Heat builds from Q1 and peaks in Q2-Q3 nationwide.
- **Hotter interior, cooler coast:** The east and southeast (Tambacounda, Kédougou, parts of Kolda/Sédhiou) are consistently hottest, while the Atlantic coast (Dakar, Thiès, Saint-Louis) remains relatively cooler.
- **Southwestern belt:** Casamance stays warm through the year in both metrics.

Where WBGT changes the picture

- **Humidity penalty:** WBGT reveals higher risk than air temperature in the south and southeast once humidity rises with the rains. Areas that are indicated as "hot" by temperature become very high risk by WBGT.
- **Dry-season relief:** In Q1, much of Senegal shows lower WBGT (29-31°C) than the temperature maps suggest, reflecting drier air and stronger winds. Temperature alone would overstate early-year heat stress for heavy work.
- **Monsoon boost:** In Q2-Q3, WBGT jumps to 33-39°C (locally higher) across the interior, expanding the high-risk footprint beyond what temperature alone indicates. Humidity, solar load, and low winds make moderate and heavy continuous work unsafe without controls.
- **Post-rains contrast:** In Q4, temperatures remain high inland, but WBGT drops markedly over much of the country except the far southeast and parts of Casamance. Temperature would overestimate risk in the north and centre during this quarter.

Quarter-by-quarter contrasts

- **Q1.** *Temperature*: Warm to hot almost everywhere, especially the interior. *WBGT*: Broad low-to-moderate heat stress (29-31°C). Dry heat keeps physiological strain lower than thermometer values imply.
- **Q2.** *Temperature*: Very hot, with the east/southeast showing highest values. *WBGT*: Sharp rise as rains begin. High-risk belt spreads across the east, centre-east and south, exceeding 33-35°C in many locations. Risk area is broader than on the temperature maps.
- **Q3.** *Temperature*: Remains very hot across most regions. *WBGT*: Nationwide maximum. Much of the interior is near 35-39°C, with local hotspots possibly higher. This is the least safe quarter for outdoor and high-exertion tasks.
- **Q4.** *Temperature*: Remains hot inland, while the coast moderates. *WBGT*: General easing over the north and centre, while pockets of high heat stress remain in the southeast and parts of the south where humidity persists.

Spatial patterns that WBGT makes clearer

- **Coast vs interior:** The Atlantic influence reduces WBGT along the coast more than air temperature suggests, especially in Q1 and Q4.
- **Southeast hotspot:** Kédougou-Tambacounda repeatedly emerges as highest WBGT in Q2-Q3, highlighting risks for agriculture, construction, small-scale mining and road works.
- **Southern humid belt:** Kolda-Sédhiou-Ziguinchor show higher WBGT than temperature alone implies during Q2-Q3, pointing to humid-heat exposure.

Implications for labour and OSH planning

- **Trigger protections with WBGT, not temperature:** When WBGT surpasses 32-33°C, protections should be applied; at ≥ 35 °C, continuous moderate/heavy work becomes unsafe without strong controls.
- **Highest-risk window:** Q2-Q3 across the east, southeast and southern belt. Protections should be stronger during this period.
- **Safer scheduling:** Q1 and Q4 along the coast and central-north are the best windows for heat-exposed activities.
- **Urban nuance:** Dakar and other coastal cities are cooler by WBGT, but urban heat islands can still create site-level hotspots. This suggests that on-site WBGT monitoring should be maintained.
- **Sector targeting:** Prioritise agriculture, construction, transport/logistics nodes and small-scale mining in the southeast and south during Q2-Q3; apply lighter measures on the coast in Q1 and Q4.

Overall, the temperature maps show where it is hot, whereas the WBGT maps show where workers are most at risk. In Senegal, humidity and wind patterns during the rains turn Q2-Q3 into the critical season, especially away from the coast. Planning and protections should follow WBGT thresholds and the quarter-specific patterns above.

2.4. Climate projections

2.4.1. Country overview

Senegal has a predominantly Sahelian climate featuring one main rainy season (June to October) and a dry season (November to May). Historically, mean temperatures fluctuating around 27-30°C have risen by nearly 1°C since the 1970s. Rainfall is often erratic, and recent decades have seen more intense precipitation alongside prolonged dry spells. These evolving conditions heighten risks of drought, flooding, and coastal erosion, challenging development progress if not sufficiently addressed. Below are the main impacts on key industries:

- **Agriculture:** Agriculture remains a cornerstone of Senegal's economy and employment, but it is highly vulnerable to climate fluctuations. Prolonged heatwaves and droughts as well as irregular rainfall have caused poor harvests and food insecurity. For instance, the 2011-2012 drought sharply reduced crop yields and left hundreds of thousands in need.[42] In contrast, excessive rains can trigger floods that waterlog fields and destroy crops, as seen in 2012 when flooding compounded the prior drought's impact on food security.[42] Rising temperatures and shifting rainfall seasons are projected to further erode agricultural performance by aggravating water deficits for crops.[18] Overall, climate variability has led to significant year-to-year volatility in production and farm incomes. In drought years, key cash crops have seen drastic revenue declines (e.g. peanut revenues fell by ~74% and millet/sorghum by 60% in a severe drought),[42] underscoring the sector's climate sensitivity. These challenges also force Senegal to import about 60% of its cereal needs,[18] as domestic output cannot meet demand under unstable climate conditions.
- **Fishing** is critical for Senegal, as it is the second-largest employer and a key source of protein and exports.[4,18] Yet, climate variability and overfishing have put this sector under stress. Changes in sea temperature and ocean chemistry are affecting fish migration and spawning. Warming waters and more frequent marine heatwaves can disrupt coastal ecosystems, contributing to declining fish stocks .[18] Moreover, the degradation of protective ecosystems such as mangroves (due in part to climate factors and human pressure) reduces fish nursery areas, further impacting catches.[18] Many coastal fishing communities have reported smaller catches and must venture farther offshore.[4,18] Extreme weather also affects fisheries: rough seas and storms during an irregular rainy season can limit the days that artisanal fishers can safely go out.[18] These climate-induced challenges to fisheries threaten livelihoods and food security in coastal areas, underscoring the need for sustainable management and climate adaptation in the sector.
- **Mining and Extractive Industries:** Senegal's mining sector (phosphates, gold, mineral sands) has grown in economic importance, but it too faces climate-related constraints. As mining operations are water-intensive, increasing heat and prolonged dry spells exacerbate water scarcity for mineral processing.[43] This is a significant concern in Senegalese arid inland regions, where competition for limited water resources is rising. Conversely, heavier rainfall and flash floods during the rainy season can disrupt mining activities – flooding of pits, road washouts, and equipment damage have been observed to halt production and incur high costs.[43] Coastal extractive activities face additional risks: sea-level rise and coastal erosion have already forced measures like banning sand mining in some areas to protect shorelines.[18] In summary, climate variability increases operational risks for mining through water stress and infrastructure damage, potentially reducing output and raising costs.

[42] National Agency for Civil Aviation and Meteorology of Senegal (2012). Climate risk and food security in Senegal - Analysis of climate impacts on food security and livelihoods.
[43] United Nations Environment Programme (2024). Climate risks in the metals and mining sector. Geneva.

- **Manufacturing:** Manufacturing in Senegal (including agro-processing, textiles, chemicals, and cement production) is indirectly affected by climate variability primarily through supply chain and infrastructure channels. Many industries rely on agricultural inputs, so climate-driven variability in farm output can impact manufacturing. For instance, a drought or heavy rainy season that slashes groundnut or cotton harvests will leave processing factories underutilized and cut export volumes.[42] Energy supply is another vulnerability, as hydropower from the Senegal River and other power infrastructure can be strained by low river flows or storm damage. Likewise, extreme weather events have damaged roads, bridges, and power lines, disrupting transportation of raw materials and finished goods.[42] Higher temperatures also pose a productivity challenge in factories and construction sites, as excess heat can slow worker output or require costly cooling. While the manufacturing sector is less directly climate-dependent than agriculture, it suffers collateral impacts when climate shocks hit the economy, often leading to slower industrial growth in bad climate years.
- **Services:** The service sector, which is the largest contributor to Senegal's GDP, experiences a mix of indirect and direct climate impacts. Finance, banking, as well as information and communication technologies are mainly affected through broader economic disruptions. For instance, extreme weather can damage telecom infrastructure or interrupt business operations and client incomes.[18] Floods in cities have periodically forced banks, offices, and markets to close, highlighting the need for climate-resilient urban planning.[4,18] Tourism is another service industry acutely exposed to climate variability. Senegal's coastal tourism hubs, including the Petite Côte around Saly, the historic city of Saint-Louis, as well as resorts in Casamance, are vulnerable to beach erosion, storm surges, and sea-level rise.[18] All of the country's major tourist infrastructure lies along the coast, where erosion of 1-2 meters per year has been observed on some sandy beaches.[18] This has already damaged hotels and roads and threatens heritage sites, reducing the destination's appeal and tourism revenues.[4,18] Additionally, increasing heat waves and unpredictable weather can deter tourists during the traditionally mild dry season.

Taken together, these climate challenges emphasize the need for robust adaptation strategies to protect both the environment and the livelihoods of communities dependent on agriculture and tourism. Detailed climate change trends against natural variability are illustrated in Figure 4. These trends illustrate a consistent upward trend in temperatures, indicating significant warming (Figure 4, top left graph), as well as that warming has become more pronounced in Senegal during the recent decades (particularly in the period 2010-2014) (Figure 4, top right graph). In addition, the available evidence reveals a clear shift in the distribution of average mean surface air temperatures in Senegal in the 30-year period until 2014 (Figure 4, bottom left graph). Finally, the evidence gathered thus far shows an increasing frequency and intensity of extreme temperature events (Figure 4, bottom right graph).

Collectively, the available evidence demonstrates a clear and accelerating warming trend in Senegal in the 30-year period until 2014:

- Average maximum temperatures have increased significantly, as indicated by the shift in distributions over recent decades.
- The occurrence and intensity of extreme temperature events, particularly in the warmer months, have grown substantially since 2010.
- Monthly temperature trends reveal that warming is not limited to specific seasons but it occurs almost the entire year.
- The trends highlight the growing impact of climate change in Senegal, posing significant challenges to the environment, economy, and public health.

Figure 4. Climatological averages and trends of change against natural climate variability in Senegal during the period 1985-2015: average mean surface air temperature with linear trend lines per decade (top left); average mean surface air temperature monthly trends (top right); change in distribution of average mean surface air temperature (bottom left); change in intensity of extreme daily maximum temperature events (bottom right).



2.4.2. Climate change scenarios

To understand how future heat conditions might affect work in Senegal, the present study uses four "storylines" known as Shared Socioeconomic Pathways (SSPs). These scenarios were used by the IPCC Sixth Assessment Report[44] to describe different ways our society might evolve based on our choices about energy use, technology, and environmental policies. The scenario characteristics are summarized in Table 1.

Following standard practice,[44] the present analysis uses codes that combine the SSP number with an expected level of greenhouse gas influence – measured as radiative forcing in watts per square meter (W/m^2) – by the year 2100. The radiative forcing level indicates the strength of the warming effect observed at the end of the century, resulting in the following codes: SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5.

It is important to note that there are several other SSPs and radiative forcing combinations available.[44] However, the present study focuses only on these four scenarios because they represent a wide range of potential futures – from a highly sustainable pathway to one that relies heavily on fossil fuels – and provide clear contrasts in terms of expected climate impacts. This selection helps illustrate the range of possible outcomes in a straightforward manner while keeping the analysis accessible and focused.

[44] IPCC (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. V. Masson-Delmotte, P. Zhai, A. Pirani et al. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, Intergovernmental Panel on Climate Change.

What are the SSPs?

The SSPs are narratives used by climate scientists to explore how different levels of greenhouse gas emissions might impact our world. In simple terms, they help us imagine a range of possible futures: from a sustainable world with clean energy to one that continues heavy use of fossil fuels.

Table 1. Characteristics of the global SSPs used in the present study.

SSP	Scenario	Estimated warming (2041-2060)	Estimated warming (2081-2100)	Very likely range in °C (2081-2100)
SSP1-2.6 (Sustainability Pathway)	**Low GHG emissions** CO_2 emissions cut to net zero around 2075	1.7	1.8	1.3 – 2.4
SSP2-4.5 (Middle of the Road Pathway)	**Intermediate GHG emissions** CO_2 emissions around current levels until 2050, then falling but not reaching net zero by 2100	2.0	2.7	2.1 – 3.5
SSP3-7.0 (Regional Rivalry Pathway)	**High GHG emissions** CO_2 emissions double by 2100	2.1	3.6	2.8 – 4.6
SSP5-8.5 (Fossil-fueled Development Pathway)	**Very high GHG emissions** CO_2 emissions triple by 2075	2.4	4.4	3.3 – 5.7

Note: Detailed information for the methods used to calculate the SSPs-related analyses can be found in Annex 1.

Key: GHG = greenhouse gas.

The four scenarios of the future considered in the present study are as follows:

- **SSP1 – Sustainability (Taking the Green Road):** In this scenario, countries work together to adopt clean energy and sustainable practices. As a result, global warming is limited, with temperature increases by the year 2100 of about 1.3°C to 2.4°C above pre-industrial levels. The "2.6" added next to the SSP1 code indicates that the warming influence (radiative forcing) is expected to reach roughly 2.6 W/m^2 by 2100.

  On the development front, in this scenario the world shifts gradually, but steadily, toward a more sustainable path, characterized by more inclusive development and a respect for environmental issues. Investments in education, health, and social protection accelerate the demographic transition, while policy reforms internalise environmental costs and improve stewardship of global commons. Economic objectives broaden from pure GDP growth to human-well-being; material consumption grows slowly and becomes markedly less resource- and energy-intensive. As a result, both inter- and intra-country inequality decline.
- **SSP2 – Middle of the Road:** This scenario follows current trends with moderate improvements in technology and environmental policies. This results in a moderate temperature rise of approximately 2.1°C to 3.5°C by the year 2100. The "4.5" added next to the SSP2 code means the radiative forcing is projected to be around 4.5 W/m^2 by 2100.

The socio-economic and technological trends in this scenario largely continue along the historical patterns. Development and income growth proceeds unevenly, with some countries making relatively good progress while others perform below expectations. Moderate population growth levels off after mid-century and resource efficiency improves gradually, yet progress toward the Sustainable Development Goals (SDGs) is uneven. Environmental pressures ease in some areas but persist in others; vulnerability to shocks remains significant where institutions are weak. Income inequality persists or marginally improves, while the challenges for addressing vulnerability to societal and environmental changes persist.

- **SSP3 – Regional Rivalry (A Rocky Road):** In this pathway, countries tend to prioritize national interests over international cooperation, leading to slower progress on clean technologies and climate policies. This scenario could lead to higher warming of about 2.8°C to 4.6°C, due to a radiative forcing level near 7.0 W/m^2 by 2100, which is reflected in the SSP3 code used in the present study.

  In this scenario, geopolitical fragmentation, resurgent nationalism and concerns over security lead countries to prioritise domestic or, at most, regional self-sufficiency. Countries prioritize achieving energy and food security goals within their own regions at the expense of broader-based development. Trade barriers rise and investment in education, technology and cross-border cooperation declines. Economic development is slow, consumption is material-intensive, inequalities persist or worsen (particularly in emerging economies), and environmental degradation accelerates in several regions. Population growth stagnates in industrialized but rises fast in developing countries.

- **SSP5 – Fossil-Fueled Development (Taking the Highway):** This future envisions rapid economic growth powered largely by fossil fuels, with limited efforts to limit emissions. This pathway may lead to the highest warming, with temperature increases exceeding 5°C by the year 2100. The "8.5" added next to the SSP5 code reflects an expected radiative forcing of approximately 8.5 W/m^2 by 2100.

  Integrated global markets and robust institutions foster technological breakthroughs in this scenario. There are also strong investments in health, education, and institutions to enhance human and social capital. The strong faith in markets and innovation drives rapid economic expansion and rising living standards. These factors lead to rapid global economic growth, while global population peaks and declines by the end of the century. However, growth is powered by abundant fossil fuels and energy-intensive life-styles. Local environmental issues such as air pollution are successfully managed, and confidence grows in large-scale technological fixes, including potential geo-engineering.

The IPCC Sixth report does not estimate the likelihood of the four tested scenarios. The rise in heat levels will depend on which mitigation pathway and policies countries collectively and independently pursue.[44]

The tested SSPs are not predictions but rather tools that help explore a range of possible futures. By comparing these outcomes, the present study illustrates how different policy and economic choices today could influence the working conditions and heat stress risks in Senegal tomorrow.

Implications of SSPs for labour markets and policy interventions

From an ILO standpoint, the SSPs highlight differing socioeconomic and governance contexts that affect labour markets. For instance, SSP1's focus on sustainability and equity could spur the creation of green jobs and improved working conditions, while SSP3's emphasis on regional rivalries and weak collaboration might hamper labour standards and stifle investment in social protection. SSP5 suggests robust economic growth but continued dependency on fossil fuels, which could raise long-term occupational risks in certain industries.

Combining the SSPs with different greenhouse gas concentration trajectories allows for comprehensive assessments of future risks and opportunities. The SSPs are used to test labour policies, design social protection measures, and plan for just transitions to low-carbon industries. By anticipating how diverse SSPs shape workforce needs and climate challenges, stakeholders can develop strategies that safeguard workers' well-being and promote sustainable and inclusive growth.

Connecting global SSPs to national strategies for Senegal

While the SSPs are developed as global scenarios, they provide critical insights for national decision-makers, including those in Senegal. These scenarios illustrate how different paths in energy use, economic growth, and policy decisions could shape the climate and, consequently, the environmental conditions that affect daily life and work. For Senegal, the varying outcomes depicted by the SSPs – ranging from sustainable pathways with limited warming (SSP1-2.6) to fossil-fueled development leading to severe warming (SSP5-8.5) – are directly linked to the country's future labour conditions, economic stability, and public health.

By considering these global SSPs, Senegalese policymakers can better understand the potential risks and opportunities that different climate futures may bring. For instance, adopting policies aligned with a more sustainable scenario (e.g., SSP1-2.6) could help mitigate the severity of heat stress, protect worker health, and reduce economic losses from reduced productivity. Conversely, inaction or insufficient adaptation measures (e.g., SSP5-8.5) may expose Senegal to extreme heat conditions, with significant repercussions for labour productivity and overall economic resilience. In essence, the global SSPs are not abstract projections. They serve as practical tools that inform national strategies, enabling Senegal to tailor its climate adaptation and economic policies to protect its citizens and secure a more stable, sustainable future.

2.4.3. Future heat conditions

The monthly maximum average environmental temperature during the reference historical period (1985-2014) ranged between 35°C and 36°C, while the WBGT for the same period ranged between 33°C and 34°C (Figure 5). Across all SSPs, the analysis suggests a clear warming trend, with varying degrees of severity depending on the scenario. Even in the most optimistic scenarios (SSP1-2.6 and SSP2-4.5), Senegal will face increases of 2-3°C environmental temperature and 2°C WBGT. The scenarios with high emissions (SSP3-7.0 and SSP5-8.5) suggest more significant warming of up to 6°C environmental temperature and 5°C WBGT. Without effective adaptation strategies, these would lead to significant health impacts and severely reduce the capacity to perform manual labour.

Figure 5. Average maximum environmental temperature (top) and WBGT (bottom) with 95% confidence intervals in the reference historical period (1985-2014) and until 2100 across the different SSPs.

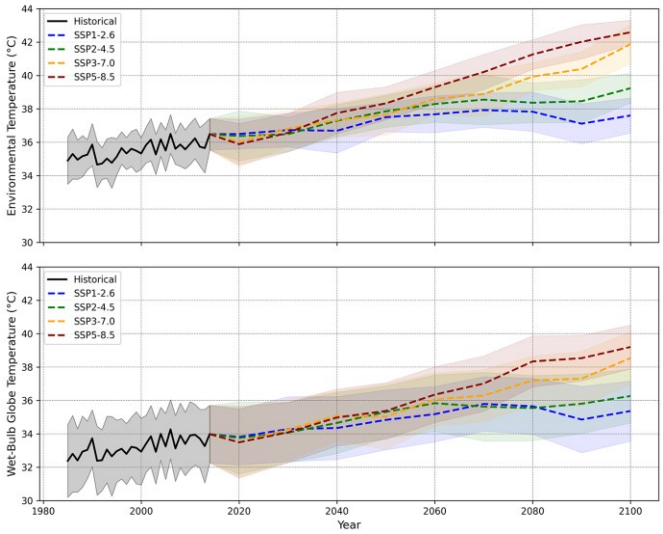


Figure 6 illustrates the change in environmental temperature compared to the reference historical period across the different SSPs and at different time points until the end of the century. The maps show a clear warming trend across Senegal in every scenario and at every time step. By 2040 the country is already about 1-2°C warmer than the 1985–2014 baseline. Differences between scenarios are small at that point.

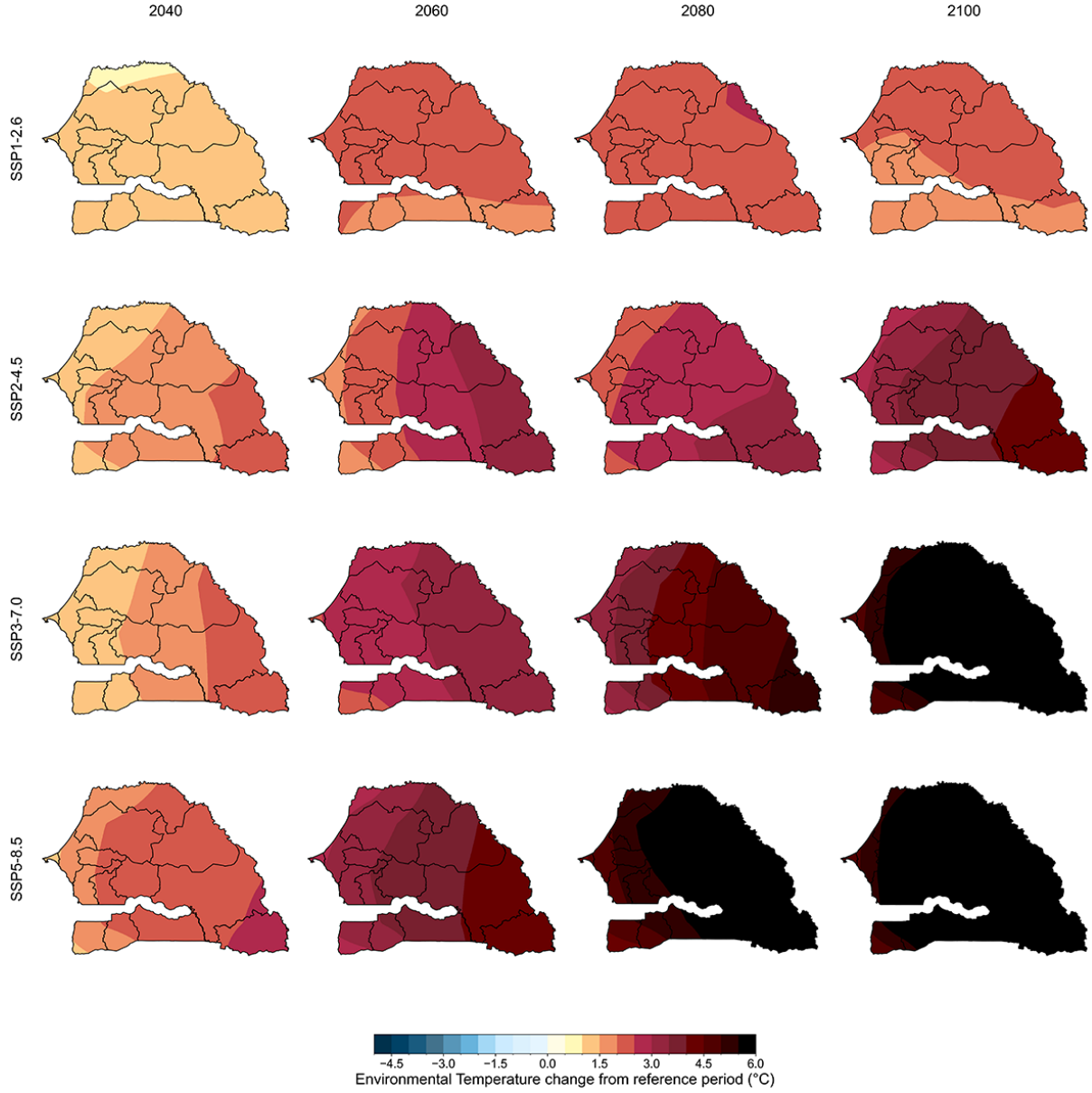
After mid-century the pathways separate. In SSP1-2.6 the rise slows and tends to level off near 2.0-2.5°C by 2100. In SSP2-4.5 most areas climb to roughly 3-4°C by the end of the century. Under SSP3-7.0 warming accelerates after 2060 and reaches about 4-5°C by 2100. SSP5-8.5 shows the steepest increase, with large parts of the country approaching 5-6°C by the 2080s and remaining near the top of the scale by century end. The gap between a Paris-aligned path and a high-emissions path is therefore on the order of 3°C by 2100.

Warming is not uniform in space. The Atlantic coast warms less than the interior throughout the period, especially under SSP1-2.6 and SSP2-4.5. The strongest increases appear in the east and south-east, particularly toward Kédougou and Tambacounda. The Casamance and the lower Senegal River valley warm markedly but

remain milder than the far interior in most panels. This west-to-east gradient is present in all scenarios and becomes more pronounced as warming grows.

Two practical messages emerge. First, a near-term increase of around 1-2°C is already locked in. Adaptation planning around heat-safe work hours, water, shade and ventilation, as well as urban design is needed even in the 2030s and 2040s. Second, climate change mitigation matters for late-century outcomes. Keeping to SSP1-2.6 holds typical hot-season maxima several degrees lower than under SSP5-8.5. Fewer days cross critical thresholds for safe work, and the season of intense heat is shorter, especially along the coast and in urban areas such as Dakar.

Figure 6. Change in the average maximum environmental temperature in Senegal compared to the reference historical period (1985-2014) across the different SSPs and at different time points during this century.

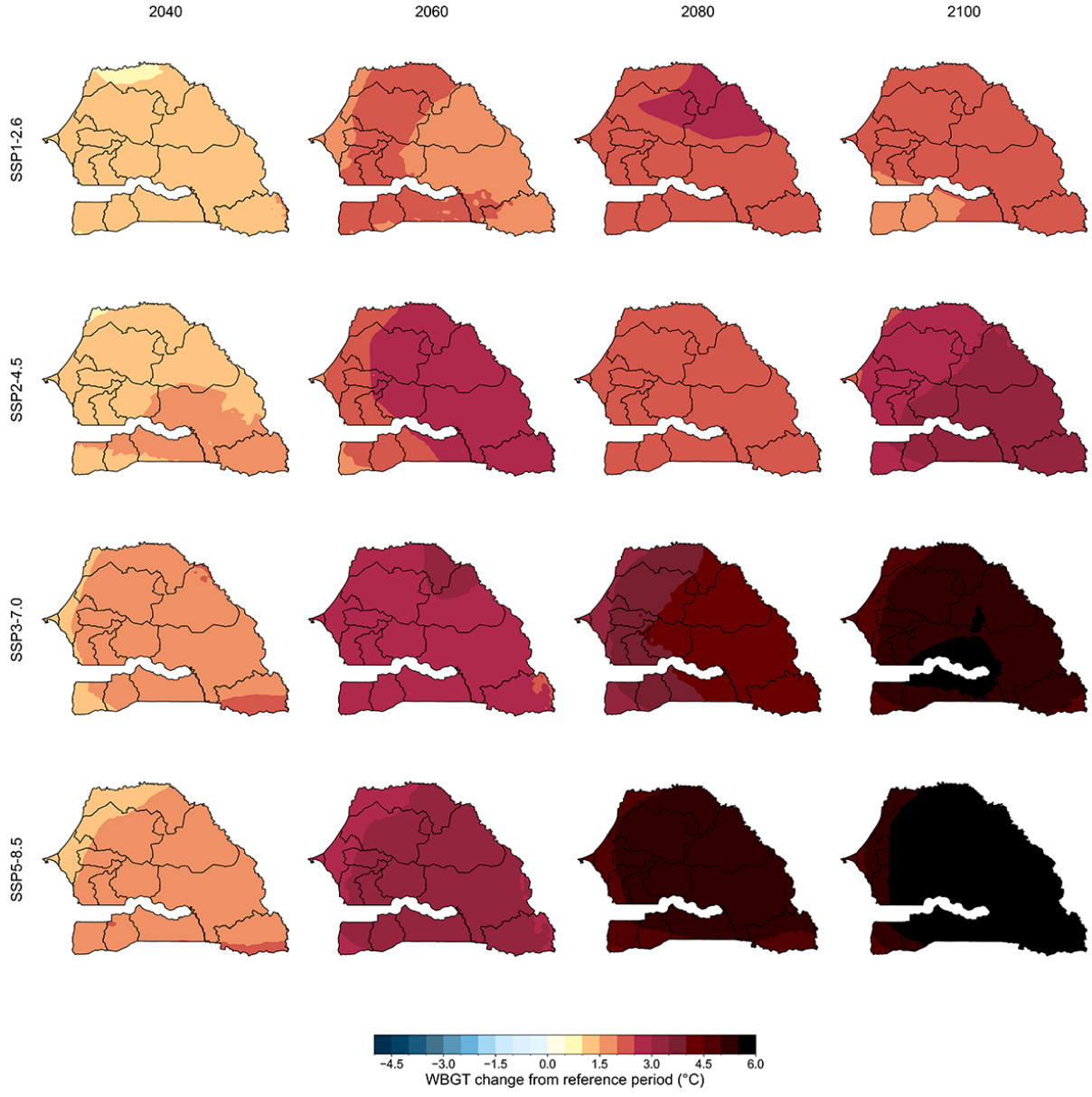


Overall, every scenario points to a hotter Senegal, with faster warming after 2060 and larger increases inland than on the coast. The choice of global pathway sets the scale of the late-century burden. A low-emissions path

limits the rise to roughly 2.0-2.5°C, while a high-emissions path pushes much of the country toward 5-6°C above the historical period.

The change in WBGT compared to the reference historical period across the different SSPs and at different time points until the end of the century is illustrated in Figure 7. The maps show a clear rise in heat stress across Senegal this century. The increase appears in every scenario and at every time point. By 2040 most areas are about 1-2°C warmer in WBGT than the historical period. Differences between scenarios are small at this stage. After 2060 the paths separate. In the low-emissions path the rise slows and levels off near 2°C by 2100. In the intermediate path many areas reach roughly 3-4°C degrees above the historical period by late century. In contrast, high-emissions futures change the picture sharply. Under SSP3-7.0 and SSP5-8.5 the increase becomes steep after mid-century. Large parts of the country approach 5-6°C of additional WBGT by 2080 to 2100. The spatial pattern is fairly uniform, with slightly larger increases inland and in the southeast. Coastal regions show a small early advantage that fades as warming intensifies. By late century the difference between coast and interior narrows.

Figure 7. Change in the average maximum WBGT in Senegal compared to the reference historical period (1985-2014) across the different SSPs and at different time points during this century.



These changes have direct effects on work. A 1-2°C rise already pushes many days over key safety thresholds for moderate and heavy tasks. A 5-6°C rise turns long parts of the hot season into periods when continuous outdoor work is unsafe without strong controls. Considering these impacts, climate change mitigation plays an important role. Keeping to a Paris-aligned path limits late-century WBGT to about 2°C above the historical period. A high-emissions path adds roughly 3-4°C extra degrees on top of that. The gap means many fewer hours lost to heat, fewer heat illnesses, and smaller GDP losses. In summary, planning should assume a near-term shift of 1-2°C and act now on protection measures. The national burden after mid-century will then depend on the global path taken and on how quickly workplace standards, cooling, and scheduling are scaled.

3. Loss of work capacity by sector of activity

3.1. Overview of economic activity sectors

Senegal's economy is supported by a diverse set of industries. Agriculture remains essential for rural livelihoods, while mining and manufacturing are gradually expanding. Services, especially finance and tourism, account for a significant share of GDP. Meanwhile, construction continues to grow alongside public infrastructure investments. Transport, logistics, and trade play a vital role by connecting domestic markets to broader regional networks. The following section offers a recent snapshot of each major industry, highlighting key regulatory updates. Drawing on official data, it underscores the country's evolving economic environment over the last five years and its prospects for sustained development.

- **Agriculture:** Agriculture contributes about 15-16% of Senegal's GDP and employs roughly 30% of the workforce.[45] The sector has seen moderate growth in the past five years, aided by favourable rainfall and government support (such as subsidies for inputs).[5] However, productivity remains vulnerable to drought and climate variability in this Sahelian country.[45] The government's Plan for an Emerging Senegal prioritizes agriculture, with plans to invest about 4 USD billion in irrigation, rural roads, credit access via a guarantee fund, storage facilities, and other measures to boost agricultural output.[45]
- **Construction:** Construction has been a major engine of growth, driven by large infrastructure projects. The sector's GDP share averaged an estimated 7% in recent years, and it generated rising employment, with construction jobs more than tripling from 335,000 in 2001 to 1.16 million in 2017.[46] Growth slowed during COVID-19 but has rebounded alongside new projects. The government shifted from public investment-led growth in the first phase of the Plan for an Emerging Senegal to a Public-Private Partnership model in the second phase, passing a new Public-Private Partnership law in 2021 to spur private investment.[45] Major initiatives include a new international airport, expanded highways, a regional express railway, a bus rapid transit system, and a 100,000 affordable housing program.[45]
- **Manufacturing:** Manufacturing accounts for roughly 15% of GDP in Senegal[47] but represents a relatively small portion of employment.[46] Over the past five years, the manufacturing sector has grown modestly, but the industrial base remains narrow and under-diversified.[5] The government has introduced policies to accelerate industrialization, including establishing special economic zones and adopting a new industrial policy to attract investment and boost competitiveness.[48] Tax incentives and infrastructure improvements (e.g. the new industrial park in Diamniadio) are part of efforts to expand manufacturing, though progress has been gradual.[5]
- **Mining and extractives:** Mining and extractive industries contribute a small share of GDP, about 3-5% in recent years.[46] Phosphates and gold are the principal mining outputs, and new oil and gas fields have been under development.[46] Employment in this sector is low, well under 5% of the workforce, due to its capital-intensive nature.[46] In the past five years, output from existing mines has been steady, and significant investment has poured into hydrocarbons. First oil production was scheduled for 2023-2024 .[5] The government has updated the regulatory framework: a 2016 Mining Code governs minerals, a

[45] International Trade Administration (2024). Senegal Country Commercial Guide. U.S. Department of Commerce. Washington, DC. https://www.trade.gov/country-commercial-guides/senegal-market-overview?section-nav=11345. Accessed: 18/12/2024.
[46] Mbaye A.A., Gueye F., Beye A., Dia A.K., Mbaye M. (2021). Employment creation potential, labor skills requirements, and skill gaps for young people. A Senegal case study. Africa Growth Initiative at Brookings. Working Paper #29. Dakar, Senegal.
[47] TheGlobalEconomy.com (2023). Senegal: Share of manufacturing. https://www.theglobaleconomy.com/Senegal/Share_of_manufacturing. Accessed: 18/12/2024.
[48] African Development Bank (2024). African Economic Outlook 2024. Driving Africa's Transformation: The Reform of the Global Financial Architecture. Abidjan, Côte d'Ivoire.

2019 Petroleum Code, a 2020 Gas Code set rules for hydrocarbons, and a 2022 law established local content requirements and revenue management for oil/gas.[49]

- **Services:** Services form the largest sector of Senegal's economy, accounting for about 50-55% of GDP[50] and over half of total employment.[48] Key service industries include trade, transport, telecommunications, finance, and tourism. Growth in the service sector was robust until the COVID-19 pandemic, when it slowed sharply in 2020 as tourism (which was 9% of GDP in 2019) effectively collapsed.[51] A rebound occurred in 2021-2022, with services output expanding 6.7% in 2022, though growth fell to 3.9% in 2023 amid temporary internet and transport restrictions.[48] The government has promoted services through a digital economy strategy and a post-COVID recovery plan that prioritizes the revival of tourism,[52] alongside improvements in the business climate for finance and information and communication technology services.
- **Transportation and trade:** Transportation, logistics, and trade are critical to Senegal's economy given its role as a regional hub. These activities also provide extensive employment, as informal trade alone accounted for about 15% of jobs in 2017.[46] Dakar's port and the new Blaise Diagne International Airport which opened 2017 have bolstered logistics capacity and throughput. The government has invested heavily in transport infrastructure (roads, ports, railways) under the Plan for an Emerging Senegal to improve connectivity.[45] Projects such as the Dakar TER rail line and a new deep-water port at Ndayane aim to facilitate trade and reduce congestion. Senegal is also implementing trade-facilitation reforms and leveraging regional agreements (ECOWAS and the AfCFTA) to boost export performance.

3.2. Impacts of heat stress on work capacity

3.2.1. Link between heat stress, work intensity, and capacity to perform work

The interplay between heat stress and work intensity is a critical factor in determining an individual's capacity to perform work. High work intensity exacerbates the physiological effects of heat, leading to quicker onset of fatigue, slower work pace, and increased safety risks. Understanding this relationship is essential for developing effective workplace policies and protective measures, such as adjusted work-rest cycles and hydration protocols, which aim to mitigate these impacts and maintain productivity even in challenging environmental conditions.

When the body cannot remove enough heat to ensure that its internal temperature remains stable, this leads to a range of adverse physiological responses.[39] These responses become particularly significant in occupational settings where physical work is required.

Heat stress and the human body

When exposed to intense heat, the human body struggles to maintain its normal internal temperature. As WBGT levels increase, the body directs more blood flow to the skin in an effort to cool down.[40] This physiological adjustment places additional strain on the cardiovascular system, leading to fatigue, reduced cognitive function, and an increased risk of heat-related illnesses such as heat exhaustion and heat stroke.[40,53]

[49] l'Initiative pour la Transparence dans les Industries Extractives (2024). Sénégal Rapport ITIE 2023. Dakar, Sénégal.
[50] Statistita (2024). Senegal: Distribution of gross domestic product (GDP) across economic sectors from 2013 to 2023. https://www.statista.com/statistics/451722/senegal-gdp-distribution-across-economic-sectors. Accessed: 18/12/2024.
[51] Tourism Economics (2021). Driving the Tourism Recovery in Senegal. Oxford, UK.
[52] Sylla F. (2020). Government of Senegal's Support for Tourism and Other Key Sectors Affected by COVID-19. U.S. Department of Agriculture.
[53] Kenny G.P., Wilson T.E., Flouris A.D., Fujii N. (2018). Heat exhaustion. Handbook of Clinical Neurology; 157: 505-529.

Work intensity and metabolic heat production

The physical effort required for high-intensity work naturally produces metabolic heat.[40,54] When this internal heat generation combines with external (environmental) heat stress, the body's cooling mechanisms can be overwhelmed.[40] Workers engaged in high-intensity activities are, therefore, at a greater risk of experiencing the negative effects of heat. As the body becomes stressed by the combined internal and external heat loads, it responds by slowing down physical work as a protective mechanism. This slowdown is called "behavioural thermoregulation"[41] and it is a key factor in the observed loss of work time and, therefore, productivity.[55]

Loss of capacity to perform work

Reduced capacity to perform work under high heat stress is not only a matter of slower movement; it also includes reduced work output[55,56] and increased error rates.[57] This occurs because workers should take more frequent breaks, reduce their pace, or even stop working to avoid heat-related health risks.[58] The cumulative effect of these adjustments is a measurable loss in work time and, therefore, productivity, as well as increased risks of accidents and long-term health impacts.[38,56]

3.2.2. Projected loss of work capacity due to rising heat stress from climate change

The impact of heat stress on the capacity to perform work in Senegal was estimated using a response function for workability, based on previous methods.[59] The estimated work capacity loss in Senegal's agricultural, construction, manufacturing, mining and quarrying, services, as well as transport and trade sectors are illustrated in Figures 8-10. The estimates were computed separately for different work intensity levels (high, moderate, and low) for the historical reference period (1985-2014) and up to 2100 based on the different SSPs. Also, they show work capacity loss during a given year as well as work capacity loss due to climate change (i.e., calculated as a change from the baseline historical period 1985-2014).

During the historical period, work capacity losses in **agriculture** and **construction** (Figure 8) fluctuated between 53-58% in high-intensity work, between 39-43% in moderate-intensity work, and between 23-32% in low-intensity work. Climate change will lead to significant work capacity losses beyond the levels observed in the historical period. Under SSP1-2.6 and SSP2-4.5, climate change will cause further work capacity losses of 10-18% in high-intensity work, 15-18% in moderate-intensity work, and 15-20% in low-intensity work, reflecting relatively mild impacts due to strong climate change mitigation. In SSP3-7.0 and SSP5-8.5, climate change will lead to additional work capacity losses reaching 26% across the different work intensities by 2100, reflecting the severe impact of climate change and heat stress on work capacity. These are the most pessimistic emission scenarios, showing the highest projected losses, reflecting the severe impact of climate change and heat stress on work capacity.

In **manufacturing**, **mining and quarrying** (Figure 9), **services**, as well as **transportation and trade** (Figure 10), work capacity losses during the historical period fluctuated between 20-25% in high-intensity work, between 8-16% in moderate-intensity work, and between 2-4% in low-intensity work. During this century, climate change

[54] Poulianiti K.P., Havenith G., Flouris A.D. (2019). Metabolic energy cost of workers in agriculture, construction, manufacturing, tourism, and transportation industries. Industrial Health; 57(3): 283-305.
[55] Ioannou L.G., Tsoutsoubi L., Samoutis G., Bogataj L.K., Kenny G.P., Nybo L., Kjellstrom T., Flouris A.D. (2017). Time-motion analysis as a novel approach for evaluating the impact of environmental heat exposure on labor loss in agriculture workers. Temperature; 4(3): 330-340.
[56] Ioannou L.G., Tsoutsoubi L., Mantzios K., et al. (2025). The impact of workplace heat and cold on work time loss. Journal of Occupational and Environmental Medicine; doi: 10.1097/JOM.0000000000003332.
[57] Ioannou L.G., Mantzios K., Tsoutsoubi L., Panagiotaki Z., Kapnia A.K., Ciuha U., Nybo L., Flouris A.D., Mekjavic I.B. (2021). Effect of a simulated heat wave on physiological strain and labour productivity. International Journal of Environmental Research and Public Health; 18(6): 3011.
[58] Flouris A.D., Ioannou L.D., Dinas P.C., et al. (2019). Assessment of occupational heat strain and mitigation strategies in Qatar – Key Findings. International Labour Organization, United Nations: Doha, Qatar.
[59] García-León D., Casanueva A., Standardi G., Burgstall A., Flouris A.D., Nybo L. (2021). Current and projected regional economic impacts of heatwaves in Europe. Nature Communications; 12(1): 5807.

will lead to significant work capacity losses beyond the levels observed in the historical period. Under SSP1-2.6 and SSP2-4.5, climate change will cause further work capacity losses of 12-20% in high-intensity work, 8-18% in moderate-intensity work, and 2-5% in low-intensity work, reflecting relatively mild impacts due to strong climate change mitigation. In SSP3-7.0 and SSP5-8.5, climate change will lead to additional work capacity losses reaching as high as 40% in the highest work intensity by 2100, suggesting significant heat stress impacts and underscoring the impact of high heat exposure and the need for adaptation measures.

The paradox of work intensity and extreme heat stress

The data shown in Figure 8 indicate that work capacity losses due to climate change will be highest in low-intensity work and lowest in high-intensity work in agriculture and construction. This is explained by the extreme heat stress experienced by agriculture and construction workers in Senegal, which caused up to 58% work capacity loss during high-intensity work in the historical period, and this will reach nearly 83% by 2100 in the high-emissions scenario – an increase of 25 percentage points. On the other hand, the heat stress experienced by workers performing low-intensity work is much less significant, leading to "only" 25% work capacity losses during the historical period and increasing to over 70% by 2100 in the high-emissions scenario – an increase of 45 percentage points. Field data[55,56] shows that people working under extreme heat stress are already near their physiological limit and, therefore, any further warming beyond current levels will have less of an impact, compared to individuals performing work at lower levels of heat stress.

Overall, the key findings of this analysis are as follows:

- **Intensity matters:** work capacity losses are directly linked to work intensity, with high-intensity work across all industries facing the greatest projected losses under all scenarios. Although the impact on moderate- and low-intensity work is less severe, even these activities will experience work capacity declines, particularly under higher-emission scenarios, highlighting the pervasive impact of rising heat levels.
- **Vulnerability is unequal:** agriculture and construction show the highest work capacity losses due to increased heat stress from climate change, reaching as high as 40% by the end of the century. Manufacturing, mining and quarrying, services, transportation, and trade are also heavily impacted, but at a lesser degree.
- **Scenario divergence:** under more optimistic scenarios (SSP1-2.6, SSP2-4.5), work capacity losses remain relatively low across all intensity levels. However, in scenarios where climate action is delayed or absent (SSP3-7.0, SSP5-8.5), work capacity losses increase significantly, particularly for high-intensity work.
- **Long-term trends:** regardless of the SSP, work capacity losses generally increase towards the latter half of the century, reflecting the long-term effects of climate change on work capacity in Senegal.

This analysis emphasizes the need for targeted adaptation strategies, particularly for high-intensity labour, to mitigate work capacity losses in the context of increasing heat levels and climate change impacts.

Figure 8. Average work capacity loss (%) in Senegal during high- (top), moderate- (middle), and low- (bottom) intensity work in agriculture (left graphs) and construction (right graphs) during the reference historical period (1985-2014) and until 2100 across the different SSPs. Vertical axes in each graph show work capacity loss during a given year (right hand side axis) and work capacity loss due to climate change, calculated as a change from the baseline historical period 1985-2014 (left hand side axis). Shaded areas represent 95% confidence intervals.

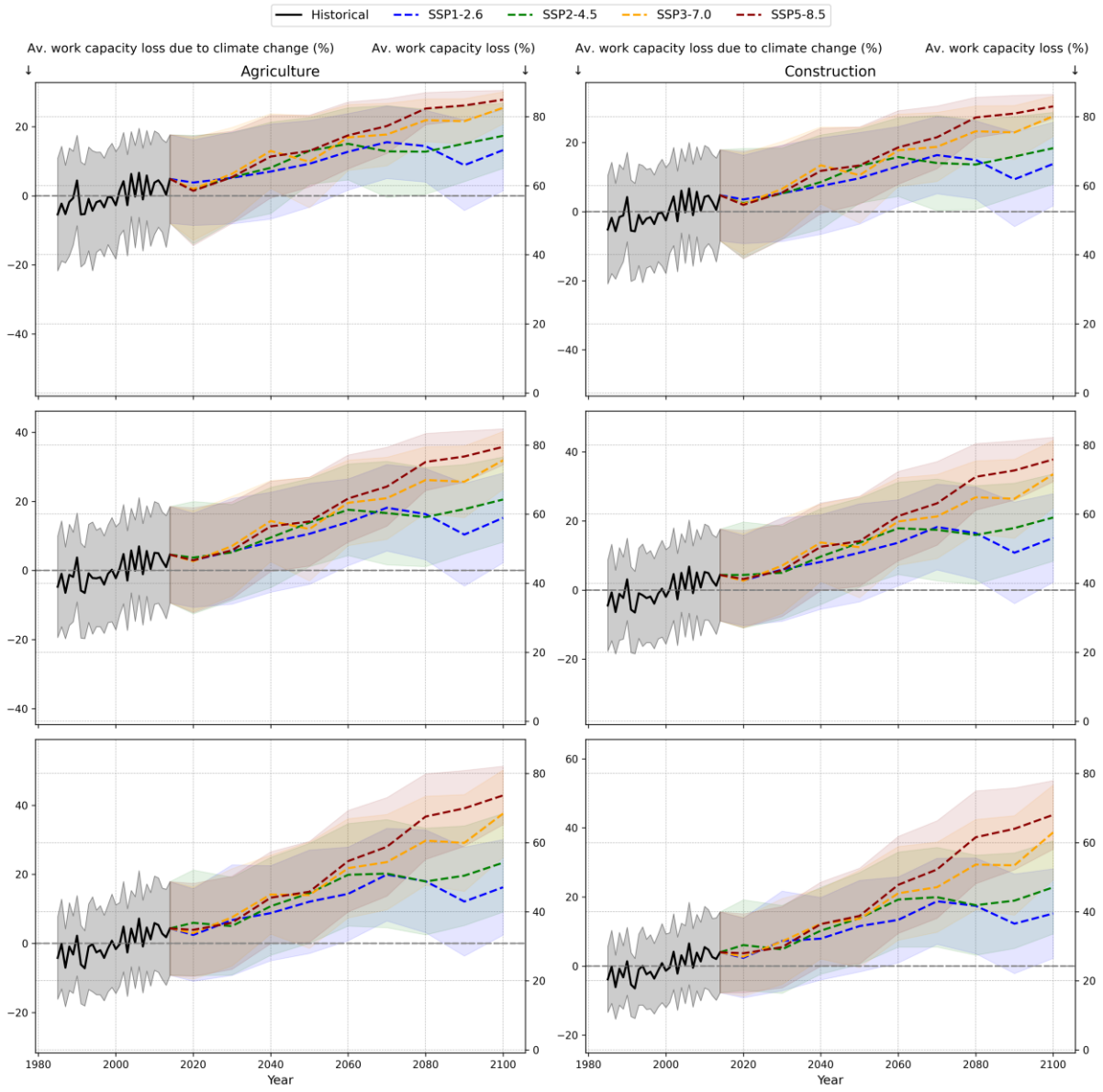


Figure 9. Average work capacity loss (%) in Senegal during high- (top), moderate- (middle), and low- (bottom) intensity work in manufacturing (left graphs) as well as mining and quarrying (right graphs) during the reference historical period (1985-2014) and until 2100 across the different SSPs. Vertical axes in each graph show work capacity loss during a given year (right hand side axis) and work capacity loss due to climate change, calculated as a change from the baseline historical period 1985-2014 (left hand side axis). Shaded areas represent 95% confidence intervals.

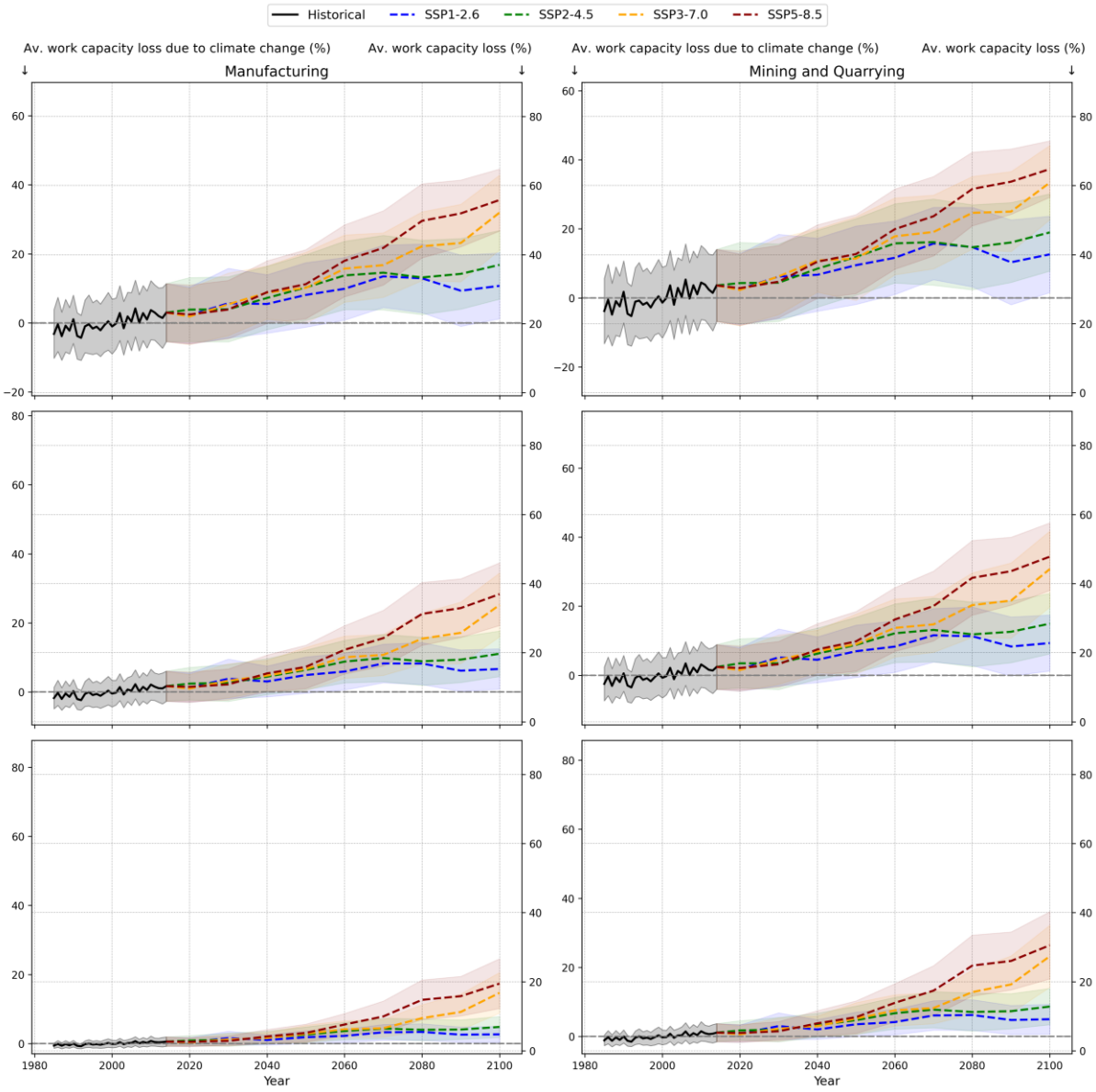
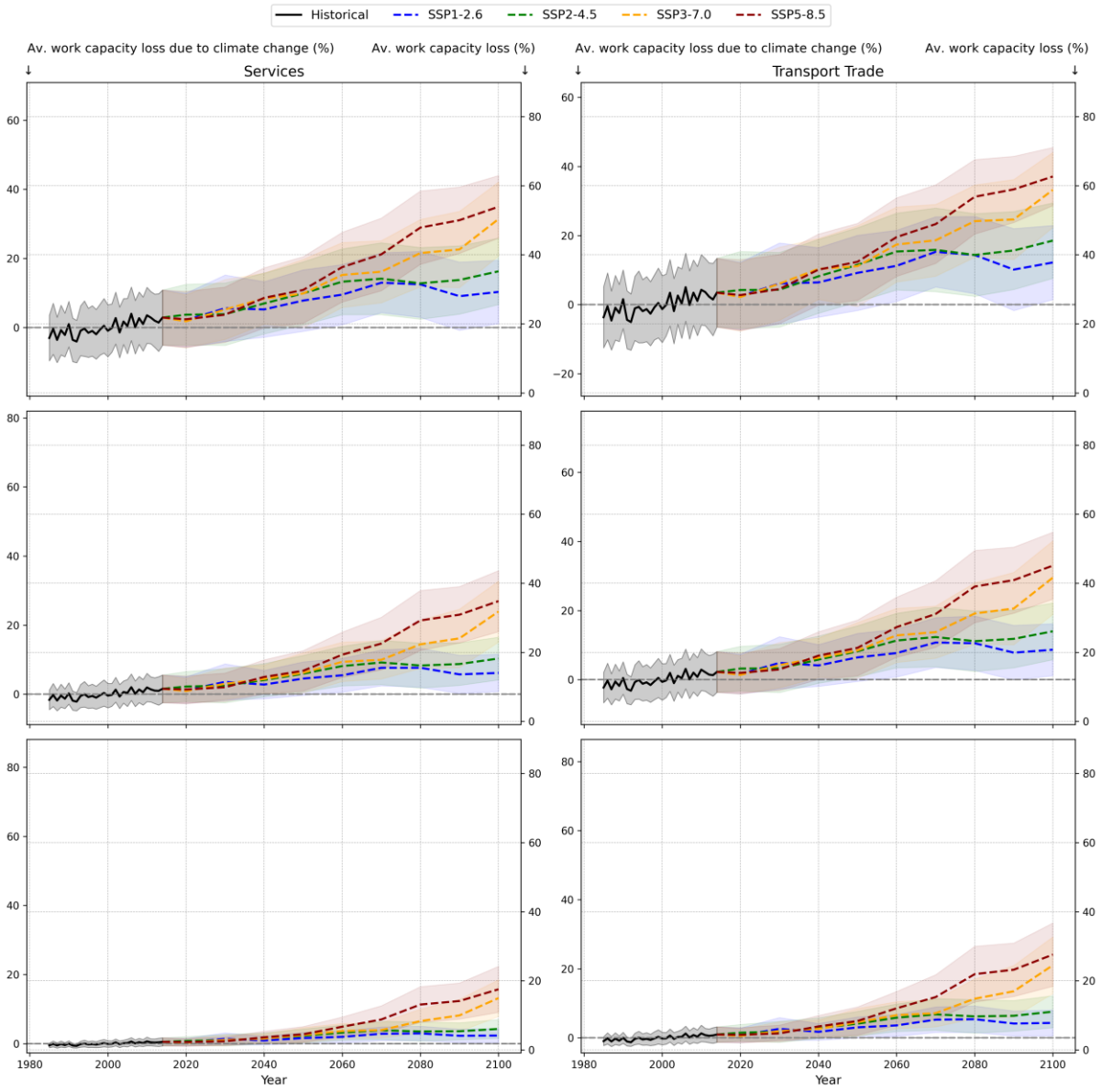


Figure 10. Average work capacity loss (%) in Senegal during high- (top), moderate- (middle), and low- (bottom) intensity work in services (left graphs) as well as transportation and trade (right graphs) during the reference historical period (1985-2014) and until 2100 across the different SSPs. Vertical axes in each graph show work capacity loss during a given year (right hand side axis) and work capacity loss due to climate change, calculated as a change from the baseline historical period 1985-2014 (left hand side axis). Shaded areas represent 95% confidence intervals.



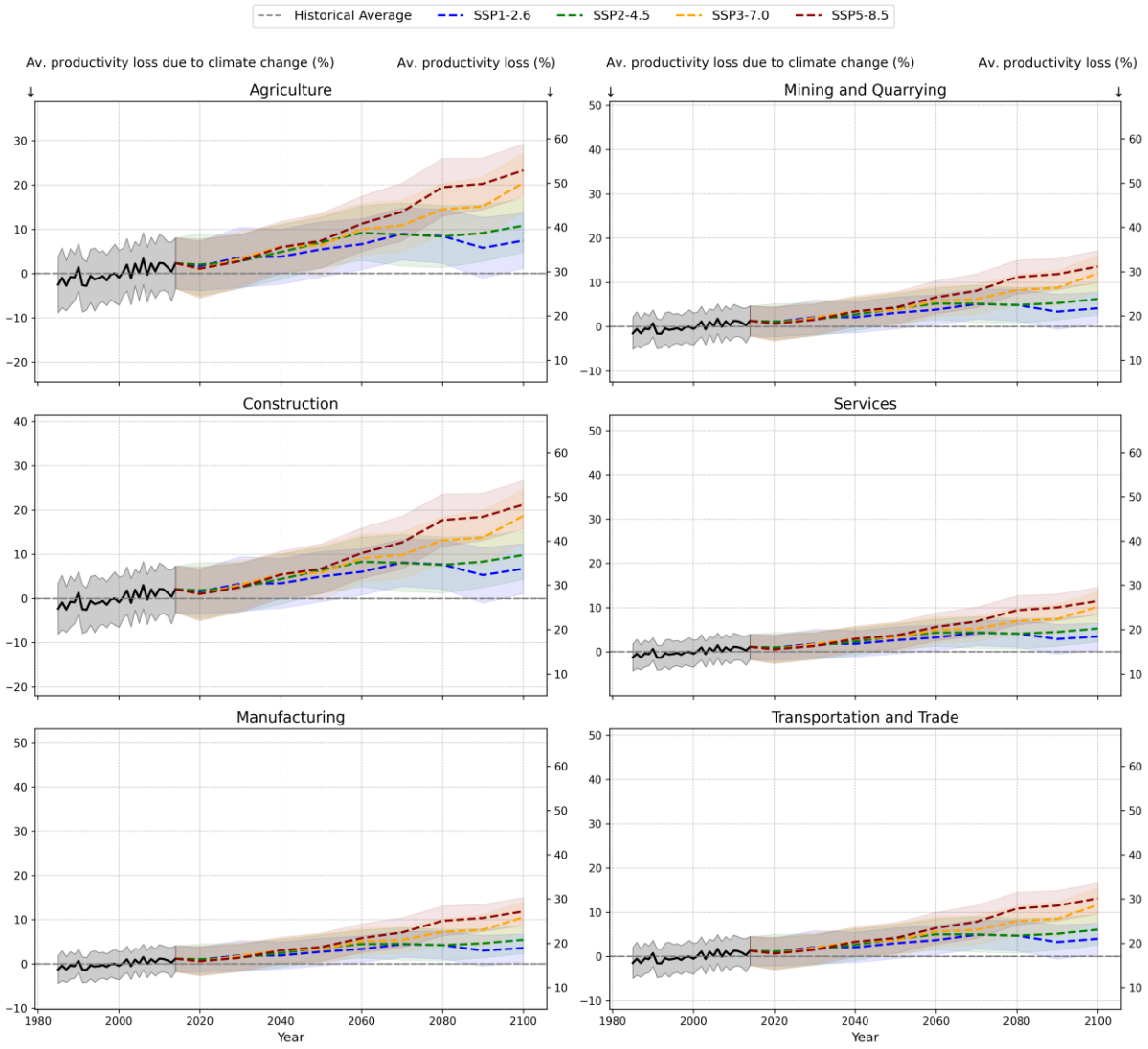
4. Loss of productivity by sector of activity

Productivity loss was estimated using a recently introduced response function linking WBGT and the time that workers allocate to work- and non-work-related activities during a typical work shift. The response function has been developed based on field studies (including studies from the ILO) that performed detailed monitoring of >600 of work shifts from different industries across multiple countries in Central America, Central and South Europe, as well as the Middle East.[38,56,57,58] This methodology provides robust estimates of productivity loss due to heat stress for the average, experienced, and acclimatized worker who performs their typical daily shift.

The estimated productivity loss by sector due to climate change and heat stress under current and projected conditions is illustrated in Figure 11. In **agriculture** and **construction**, productivity loss due to heat stress fluctuated between 27-30%, during the historical period. By 2100, under SSP1-2.6 and SSP2-4.5, productivity loss is expected to further increase by 6-10% due to climate change, reflecting relatively mild impacts due to climate change mitigation. Under SSP3-7.0 and SSP5-8.5, climate change will lead to increases in productivity loss compared to the average year of the reference historical period, reaching as high as 23% toward the end of the century. Agriculture and construction are thereby particularly vulnerable sectors to productivity loss due to climate change.

In **manufacturing**, **mining and quarrying**, **services**, as well as **transportation** and **trade**, productivity loss due to heat stress remained stable at about 16-18% during the historical period. Under SSP1-2.6 and SSP2-4.5, climate change is anticipated to further increase productivity loss by 3-7% by the end of the century. This will be higher under SSP3-7.0 and SSP5-8.5, resulting in additional productivity loss of up to 13% in these scenarios by 2100, compared to the average year within the reference period.

Figure 11. Average productivity loss in Senegal in agriculture (top left), construction (middle left), manufacturing (bottom left), mining and quarrying (top right), services (middle right), as well as transportation and trade (bottom right) during the reference historical period (1985-2014) and until 2100 across the different SSPs. Vertical axes in each graph show productivity loss during a given year (right hand side axis) and productivity loss due to climate change, calculated as a change from the baseline historical period 1985-2014 (left hand side axis). Shaded areas represent 95% confidence intervals.



5. Economic and labour market impacts

5.1. Current economic impacts

Heat stress affects not only individual workers but also has far-reaching implications for national economies. When workers are exposed to high levels of heat, they tend to slow down, take more frequent breaks, or may even be unable to work at all – all of which reduce the effective work time. This reduction in labour input at the worker level (which includes all types of labour including managerial jobs) accumulates into the loss of productivity in specific sectors of the economy (agriculture, construction etc.) and, in aggregate, directly translates into lower economic output, which is reflected in a decrease in GDP. Essentially, economic production relies on the total available work hours, and when those hours diminish due to heat stress, the overall contribution of the workforce to production is reduced.

The analysis presented in Section 4 estimates the number of work hours lost due to heat stress caused by climate change across key economic sectors. These lost work hours indicate a lower effective labour input compared to the baseline historical period 1985-2014. By applying industry- and location-specific multipliers that account for each sector's share of the economy, the corresponding loss in GDP can be estimated. These estimates unravel the GDP lost due to climate change for the present (i.e., 2023), calculated as the change in heat stress levels from the reference historical period (1985-2014), while considering the associated fluctuations in GDP and industry-specific contribution to GDP. The analysis can be then expanded to provide estimates for 2040 and 2060 according to the population, socioeconomic, and governance contexts of each SSP. The methodology used for these analyses is described in Annex 1.

The findings from the analysis on the economic impacts of rising heat stress due to climate change demonstrate that Senegal lost 2.5 billion USD more in 2023 compared to the average year during the reference historical period (1985-2014) (Table 2). The distribution of the GDP loss (in million USD) due to climate change across the country is illustrated in Figure 12. The map shows that losses are not uniform across the country. The largest losses cluster around Dakar and the western economic corridor. Smaller pockets appear around regional hubs along main roads and the port and airport links. Other regions show low absolute losses.

Table 2. Change in the contribution of each sector to GDP due to rising workplace heat stress caused by climate change, between 2023 and the reference historical period 1985-2014.

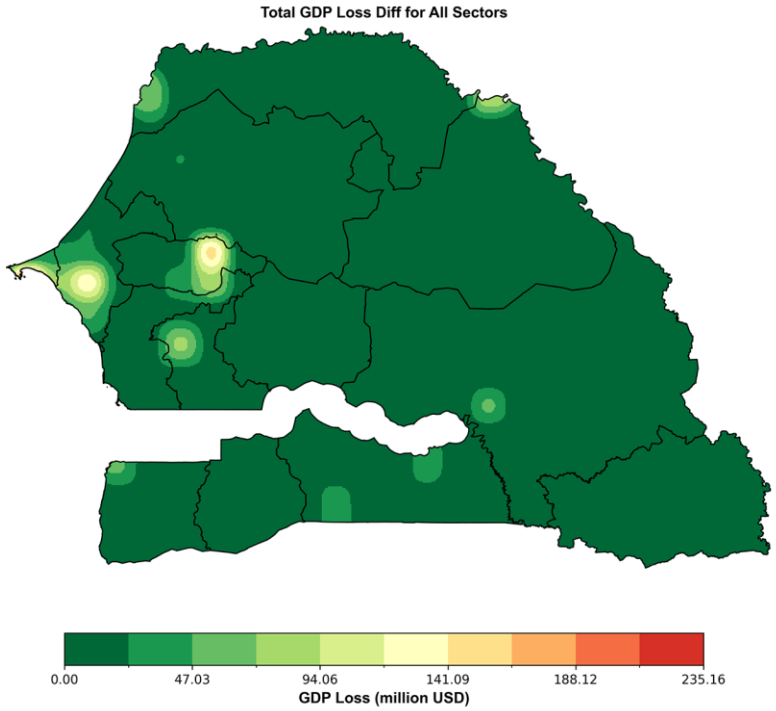
Sector	**Change in GDP**	
	*(M USD)**	*(distribution; %)*
Agriculture	-805.5	31.9
Construction	-87.7	3.5
Manufacturing	-322.5	12.8
Mining and Quarrying	-95.3	3.8
Services	-970.6	38.4
Transport and Trade	-242.5	9.6
Total GDP change	-2,524.0	

* million USD (fixed 2015 prices), with negative values indicating a GDP reduction compared to the baseline historical period 1985-2014.

The observed pattern follows the distribution of firms and workers. Most economic activities are concentrated in cities. Midday heat cuts work time and output in shops, offices, workshops, and on construction sites, while urban heat and warm indoor spaces add to the strain. Lower values outside cities do not mean low risk. Many rural and informal workers face high exposure and limited protection. The GDP loss is smaller because local output is smaller, yet the impact on household income can still be significant.

The policy message is clear. Protect workers and firms in Dakar and the main regional hubs using WBGT thresholds. Improve ventilation in indoor workplaces. Prepare heat plans for ports, logistics hubs, and industrial parks. Extend the same protections to rural outdoor work. These steps will cut current losses and help avoid bigger losses as heat rises.

Figure 12. GDP loss across Senegal due to rising workplace heat stress caused by climate change, between 2023 and the baseline historical period 1985-2014.



5.1.1. Sectoral contribution to current GDP loss

The analysis presented in Section 5.1 was also used to estimate the impact of climate change on each sector of economic activity. Specifically, the analysis estimated the change in the contribution of each sector to overall GDP due to rising workplace heat stress caused by climate change, between 2023 and the reference historical period (1985-2014). The methodology used for this analysis is described in Annex 1.

The impact of rising workplace heat stress due to climate change on each sector of economic activity is shown in Table 2. The GDP losses in the service sector far outweigh those from all other sectors, representing 38.4% of the additional GDP losses compared to an average year during the historical period. Agriculture is also heavily impacted, with 805.5 million more USD lost due to heat stress during 2023 in relation to an average year during the historical period (Table 2). Manufacturing also experienced a heavy impact, representing 12.8% of the additional GDP losses compared to an average year during the historical period (Table 2).

The regional distribution of the impact of rising workplace heat stress due to climate change on each sector of economic activity is illustrated geographically in Figure 13. The maps indicate that GDP losses cluster in and around Dakar. Smaller pockets appear along the main transport corridor and in several regional hubs. Most rural areas record low absolute losses because their local economies are smaller, not because workers are safe.

Services carry the largest toll. The Dakar metro area is the clear hotspot while smaller service losses appear around other cities. This mirrors where retail, hospitality, administration, and informal urban commerce are concentrated and where mid-day heat cuts work time. Manufacturing losses are tightly clustered near Dakar and nearby industrial zones as well as in St-Louis and Diourbel. Workshops and factories with limited cooling are sensitive to hot hours. Construction shows distinct urban hotspots, again strongest around Dakar and along

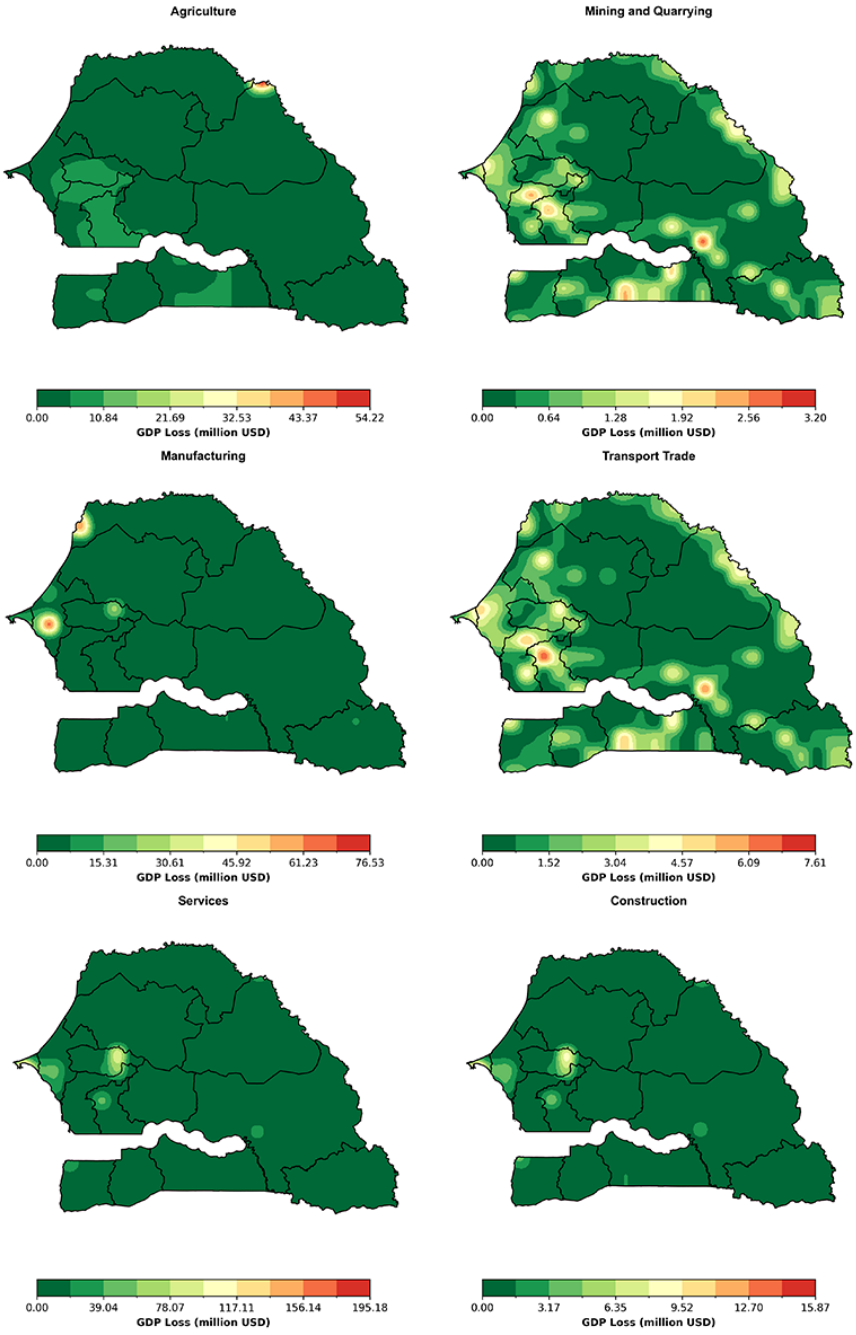
active project corridors. Agriculture losses are more spread out. Values per district are smaller than in urban services, yet the impact on rural incomes can be meaningful because many tasks are manual and outdoors. Pockets along the Senegal River valley and parts of Casamance stand out.

Transport and trade show many small nodes along highways, ports, and border posts. Delays and reduced throughput due to heat stress can still ripple through supply chains. Finally, mining and quarrying losses are also scattered and small in national totals. Individual sites show clear but localised peaks of up to a few million USD. Where a mine dominates the local economy, the effect can be large for that community.

Importantly, scales differ across the six panels, so colours cannot be compared across sectors. The consistent message is that the biggest absolute losses arise where value added and jobs are densest. That means Dakar and nearby urban centres first, then regional hubs and logistics nodes. Lower absolute losses elsewhere do not imply low risk. Workers in hot rural and peri-urban settings still face high exposure. Their economies are simply smaller.

The policy recommendation is clear. Protect workers and firms in Dakar and other hubs during hot periods. Use WBGT-based work-rest rules on worksites and in markets. Prioritise cooling and scheduling in factories and construction sites. Support rural districts with guidance for safer task timing and access to shade and hydration. These measures will cut current losses and help avoid larger losses as heat rises.

Figure 13. GDP loss across Senegal due to rising workplace heat stress caused by climate change, between 2023 and the baseline historical period 1985-2014, in each sector of economic activity. Note: due to the dominance of the service sector in Senegal's economy, it was not possible to maintain a constant range of GDP loss across all maps as the smaller size of the other sectors would prohibit an efficient illustration of the data.



5.2. Future economic impacts

The projected impact of rising workplace heat stress due to climate change on total and sectoral GDP during 2040 and 2060 across the different SSPs is presented in Table 3. Senegal's macro-economic exposure to rising workplace heat stress is set to intensify between 2040 and 2060, with outcomes highly sensitive to global emissions scenarios. Even on a Paris-aligned trajectory (SSP1-2.6), heat-related productivity losses will reduce

GDP by about 11.4% and 14% more in 2040 and 2060, respectively, relative to the losses during the average year within the 1985-2014 baseline. This is equal to an annual loss of 10.5 billion USD in 2040 and 47.6 billion USD in 2060. Should fossil-fuel development continue unabated (SSP5-8.5), rising workplace heat stress could cut 70.3 billion USD off annual national output (i.e., 15.6% of GDP) by 2060, eliminating the cumulative GDP value of several medium-sized manufacturing subsectors.

Table 3. Annual impact of rising workplace heat stress caused by climate change on GDP in Senegal during 2040 and 2060 across different SSPs, compared to the baseline historical period 1985-2014.

		Change in GDP			
		2040		**2060**	
		(M USD)[1]	*(%)*	*(M USD)*[1]	*(%)*
Agriculture	SSP1-2.6	-2,036.4	-2.21	-9,743.3	-2.88
	SSP2-4.5	-1,738.1	-2.20	-7,424.3	-2.93
	SSP3-7.0	-1,301.9	-1.97	-3,704.6	-2.59
	SSP5-8.5	-2,588.1	-2.42	-14,630.8	-3.25
Construction	SSP1-2.6	-358.7	-0.39	-1,598.7	-0.47
	SSP2-4.5	-303.7	-0.38	-1,249.4	-0.49
	SSP3-7.0	-263.3	-0.40	-764.8	-0.53
	SSP5-8.5	-435.0	-0.41	-2,359.2	-0.52
Manufacturing	SSP1-2.6	-2,776.4	-3.02	-12,106.8	-3.57
	SSP2-4.5	-2,342.2	-2.96	-9,001.2	-3.55
	SSP3-7.0	-1,930.8	-2.92	-5,114.7	-3.58
	SSP5-8.5	-3,347.8	-3.13	-17,740.7	-3.94
Mining and Quarrying	SSP1-2.6	-163.8	-0.18	-996.1	-0.29
	SSP2-4.5	-133.8	-0.17	-786.4	-0.31
	SSP3-7.0	-92.0	-0.14	-386.9	-0.27
	SSP5-8.5	-219.2	-0.20	-1,496.0	-0.33
Services	SSP1-2.6	-4,601.3	-5.00	-20,446.5	-6.03
	SSP2-4.5	-3,916.6	-4.95	-16,017.7	-6.32
	SSP3-7.0	-3,386.7	-5.11	-9,627.2	-6.73
	SSP5-8.5	-5,607.8	-5.24	-30,091.2	-6.68
Transport and Trade	SSP1-2.6	-567.4	-0.62	-2,684.3	-0.79
	SSP2-4.5	-483.4	-0.61	-2,093.4	-0.83
	SSP3-7.0	-380.8	-0.57	-1,121.2	-0.78
	SSP5-8.5	-705.3	-0.66	-3,959.0	-0.88
TOTAL	SSP1-2.6	-10,504.1	-11.41	-47,575.6	-14.04
	SSP2-4.5	-8,917.6	-11.26	-36,572.6	-14.44
	SSP3-7.0	-7,355.7	-11.11	-20,719.4	-14.49
	SSP5-8.5	-12,903.1	-12.07	-70,276.9	-15.61

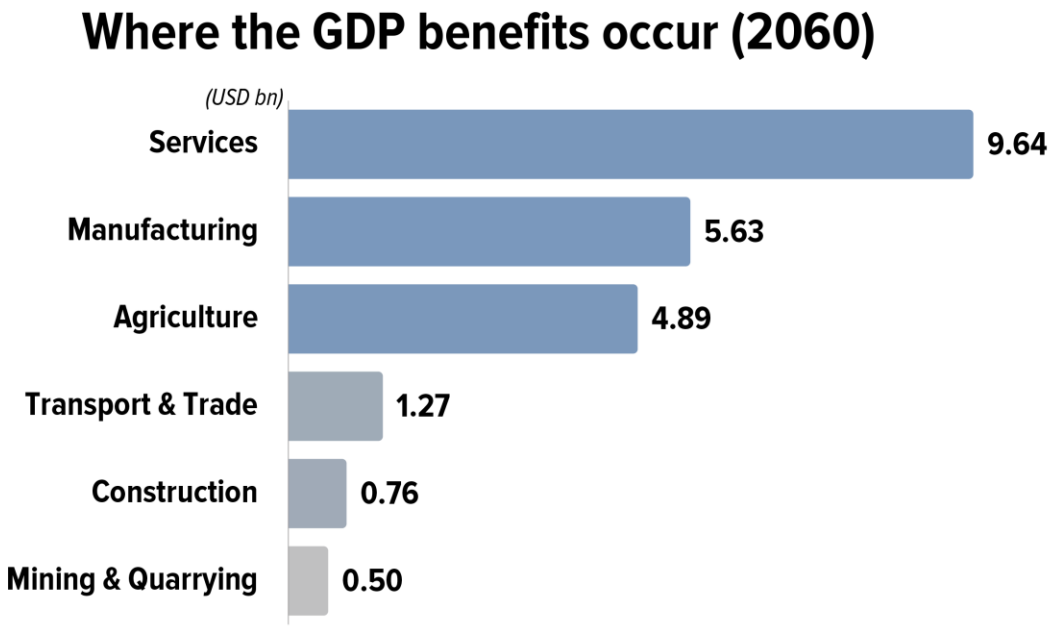
[1] million USD, fixed 2015 prices.

SSP: shared socioeconomic pathway; negative values indicate a GDP reduction compared to the baseline historical period 1985-2014.

The sectoral pattern is uneven but consistent across pathways. Services, the backbone of the Senegalese economy, bears most of the losses: 5% of GDP (4.6 billion USD) more losses in 2040 under SSP1-2.6 compared to the historical period, rising to 6.7% (30 billion USD) in 2060 under SSP5-8.5. Agriculture will record declines that deepen from 2 billion USD (SSP1-2.6, 2040) to 14.6 billion USD (SSP5-8.5, 2060). Manufacturing absorbs steady declines that rise from 2.8 billion USD (SSP1-2.6, 2040) to 17.7 billion USD (SSP5-8.5, 2060), reflecting high indoor heat loads and partial air-conditioning coverage. Similarly, construction will experience 359 million USD more losses in 2040 under SSP1-2.6 compared to the historical period, rising to 2.4 billion USD in 2060 under SSP5-8.5. Mining and quarrying are expected to experience small and steady climate change impacts ranging from 164 million USD additional losses in 2040 (compared to the baseline period), to 1.5 billion USD in 2060.

Three policy conclusions follow. First, the steep scenario gradient confirms that ambitious global mitigation (SSP1-2.6) could avert 1.6 percentage points of GDP loss by 2060 (about 22.7 billion USD in 2060), relative to SSP5-8.5. Second, domestic adaptation should prioritise heat-proofing the services economy, particularly retail, hospitality, and public administration, where the absolute loss is highest (Infographic 1). This implies accelerated investment in efficient cooling, urban heat island management and flexible work scheduling. Third, sector-specific labour regulations should anticipate that expansion in transport and trade as well as manufacturing and construction will intensify exposure to workplace heat stress. Therefore, incorporating heat stress thresholds into

Infographic 1. Sectoral GDP benefits of implementing in Senegal the decent work and sustainable development goals as described in SSP1-2.6, particularly in relation to workplace heat stress (calculated as differences between SSP5-8.5 and SSP1-2.6).



building codes, transport and agricultural extension services, as well as social-protection schemes will be critical. Anchoring these measures in Senegal's forthcoming National Adaptation Plan and Decent Work Country Programme will help safeguard both competitiveness and worker welfare as temperatures rise.

5.3. Current labour market impacts

When workers experience heat stress, they are forced to reduce their output either by working at a slower pace or by taking more frequent breaks. Over time, this reduction in effective work time accumulates and it is essential to translate the reductions in working hours into a metric that can be readily understood. The most appropriate metric is full-time equivalent (FTE) job losses, a standard indicator of economic and labour market impact. In the case of heat stress, FTE job losses describe the reduction in the number of full-time jobs that could have been sustained under optimal working conditions. This methodology allows quantifying the impact of workplace heat stress on labour markets in a standardized and comprehensible manner, facilitating comparisons across industries and informing policy decisions aimed at mitigating these adverse effects.

The conversion of lost working hours into FTE job losses is based on a standard calculation of annual working hours per worker. It is assumed that a worker takes a minimum of 14 days of leave per year. Considering a typical work schedule of 5 days per week and 8 hours per day, the total potential working hours per year are calculated as:

$$\text{Annual Working Hours} = (365\text{-}14) \times \frac{5}{7} \times 8 \approx 2006 \text{ hours}$$

The FTE job losses per industry are calculated by comparing the available work hours against the reduced work hours resulting from workplace heat stress (provided in Section 4). The difference between the total potential working hours (2006 hours per year) and the actual hours worked (after accounting for the hours lost due to workplace heat stress) represents the deficit in labour input. This deficit is then divided by the standard annual working hours (2006 hours) to obtain the number of FTE jobs lost.

The analysis used data for 2023 to describe the current impact of rising heat stress due to climate change on Senegal's labour market. Thus, estimates were expressed as the change between 2023 and the reference historical period 1985-2014, while considering the associated fluctuations in GDP.

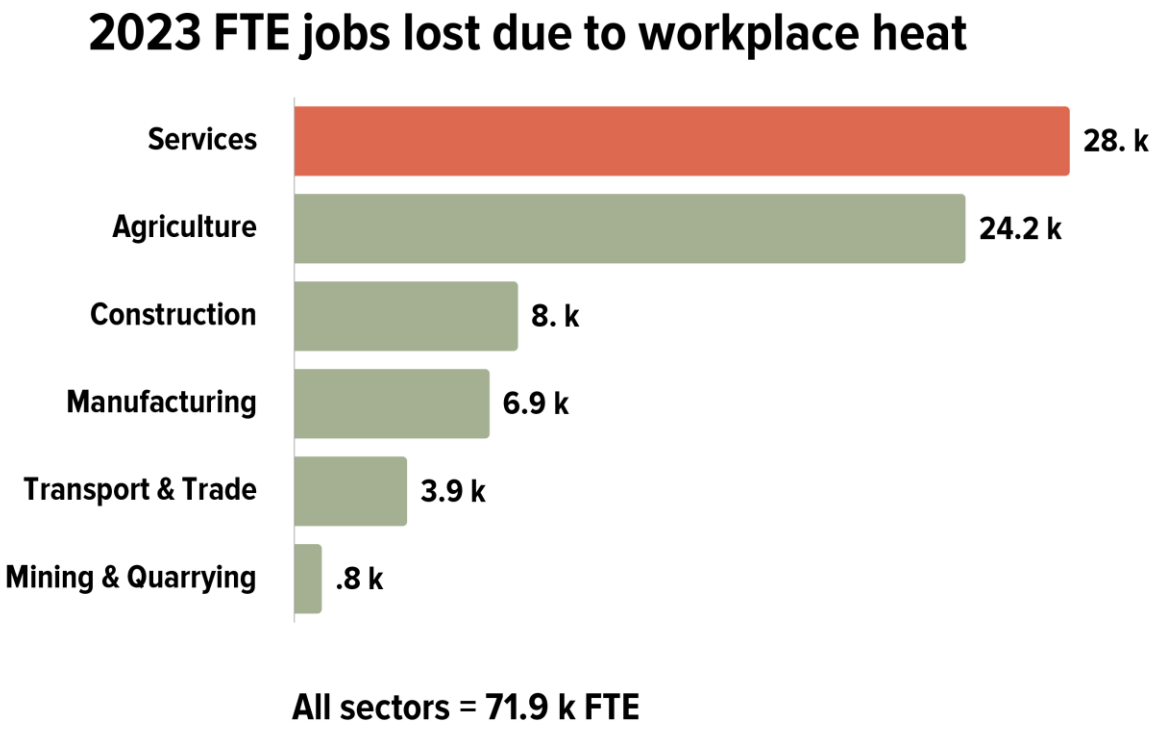
The findings in Table 4 show that the impact of climate change on Senegal's labour market is significant, with nearly 72,000 more jobs lost due to workplace heat stress during 2023 compared to the average year during the historical period. About 39% of job losses are concentrated in services, 34% occur in agriculture, as well as about 11%, 10%, and 5% in construction, manufacturing, as well as transport and trade, respectively (Table 4 and Infographic 2). The analysis also reflects a seasonal pattern where 43% of the impacts occur in Q2, reflecting the part of the years with peak heat levels. These results highlight the urgent need for adaptive policies, such as regulated work-rest cycles, access to cooling measures, and the integration of heat mitigation into occupational safety standards, to safeguard worker productivity and health in Senegal.

Table 4. Quarterly and annual impact of rising heat stress due to climate change on full-time equivalent jobs lost (proxied from work hours lost) in each sector of economic activity and across the entire economy in Senegal, calculated as the change between 2023 and the reference period 1985-2014 (negative values show losses vs reference).

Sector	Period	Available Work Hours (n)	Change in Work Hours		Change in Jobs (FTE)
			(n)	(% FTE)	
Agriculture	Q1	528,102,271	4,895,487	0.93	2,440
	Q2	534,207,500	-23,924,738	-4.48	-11,927
	Q3	540,312,729	-15,167,944	-2.81	-7,561
	Q4	540,312,729	-14,400,793	-2.67	-7,179
	Year	2,142,935,229	-48,597,988	-2.27	-24,226
Construction	Q1	173,900,094	1,000,583	0.58	499
	Q2	175,910,500	-6,251,958	-3.55	-3,117
	Q3	177,920,906	-4,890,941	-2.75	-2,438
	Q4	177,920,906	-5,828,544	-3.28	-2,906
	Year	705,652,406	-15,970,860	-2.26	-7,962
Manufacturing	Q1	320,816,637	1,224,153	0.38	610
	Q2	324,525,500	-5,625,138	-1.73	-2,804
	Q3	328,234,363	-4,681,045	-1.43	-2,334
	Q4	328,234,363	-4,816,810	-1.47	-2,401
	Year	1,301,810,863	-13,898,840	-1.07	-6,929
Mining and Quarrying	Q1	31,760,329	122,651	0.39	61
	Q2	32,127,500	-739,622	-2.30	-369
	Q3	32,494,671	-568,033	-1.75	-283
	Q4	32,494,671	-483,329	-1.49	-241
	Year	128,877,171	-1,668,333	-1.29	-832
Services	Q1	1,193,066,326	3,076,847	0.26	1,534
	Q2	1,206,859,000	-22,052,868	-1.83	-10,993
	Q3	1,220,651,674	-18,584,416	-1.52	-9,264
	Q4	1,220,651,674	-18,633,083	-1.53	-9,289
	Year	4,841,228,674	-56,193,520	-1.16	-28,013
Transport and Trade	Q1	155,265,523	586,819	0.38	293
	Q2	157,060,500	-3,485,095	-2.22	-1,737
	Q3	158,855,477	-2,682,774	-1.69	-1,337
	Q4	158,855,477	-2,305,532	-1.45	-1,149
	Year	630,036,977	-7,886,583	-1.25	-3,931
TOTAL	Q1	2,402,911,180	10,906,540	0.45	5,437
	Q2	2,430,690,500	-62,079,418	-2.55	-30,947
	Q3	2,458,469,820	-46,575,153	-1.89	-23,218
	Q4	2,458,469,820	-46,468,092	-1.89	-23,165
	Year	9,750,541,320	-144,216,123	-1.48	-71,892

n: number; FTE: full-time equivalent.

Infographic 2. Annual impact of rising heat stress due to climate change on full-time equivalent jobs lost (proxied from work hours lost) in each sector of economic activity and across the entire economy in Senegal, calculated as the change between 2023 and the reference historical period 1985-2014.



5.4. Future labour market impacts

Table 5 shows the annual projected labour market impacts of rising heat stress due to climate change during 2040 in each sector of economic activity and across the different SSPs, in relation to the reference historical period 1985-2014. The projected labour-time losses attributable to climate-induced heat stress grow markedly with the global emissions trajectory and are already substantial for Senegal by 2040. Estimates indicate that, relative to the 1985-2014 baseline, the economy will lose the equivalent of 129 thousand full-time jobs under a low-emissions pathway (SSP1-2.6). The losses rise to nearly 176 thousand full-time jobs under SSP5-8.5. In proportional terms this represents 4.4 per cent contraction in total available labour time under the most optimistic scenario and 6 per cent under unabated fossil-fuel development.

The burden is concentrated primarily in the agriculture sector, which accounts for 45.6 thousand FTE annual job losses in SSP1-2.6, rising to 67-108 thousand in the high-emissions scenarios (SSP3-7.0 and SSP5-8.5), 10.7-17.3 per cent of the sector's total labour force. Agriculture is particularly exposed given the sector's outdoor work intensity and the physiological limits of heavy manual labour in high humid-heat conditions. Services rank second, with annual job losses of 48-113 thousand FTEs (3.2% to 7.6% of sector total) across the scenario range, given that much of Senegal's retail, hospitality, and informal urban commerce occurs in environments with limited climate control. Construction follows with 14-32 thousand annual FTE job losses (6.3% to 14.7% of sector total), suggesting that existing regulations and cooling measures in construction sites and infrastructure projects remain insufficient to offset rising WBGT. Annual losses in manufacturing (12.7 to 28.5 thousand FTEs; 3.3% to 7.4% of sector total) as well as transport and trade (7.2 to 17.3 thousand FTEs; 3.9% to 9.3% of sector total) are smaller in absolute terms but remain proportionately significant given those sectors' smaller employment base. Mining and quarrying show smaller impacts (1.5 to 3.7 thousand FTEs; 4.0% to 9.7% of sector total), underscoring the advantage of mechanisation and limited workforce size.

Table 6 shows the annual projected labour market impacts of rising heat stress due to climate change during 2060 in each sector of economic activity and across the different SSPs, in relation to the reference historical

period 1985-2014. The analysis shows that, by 2060, climate-driven heat stress will remove the equivalent of 237-747 thousand FTE jobs from Senegal's economy each year, depending on the global emissions pathway. Estimates show that under the Paris-consistent trajectory (SSP1-2.6) Senegal will annually lose 237 thousand FTEs, or about 8.1 per cent of total labour force. The toll rises sharply to 417 thousand FTEs under SSP2-4.5, 350 thousand under SSP5-8.5, and peaks at 747 thousand under SSP3-7.0, where heat cuts 25.4 per cent more aggregate work hours compared to the average year within the historical period.

Losses are highly concentrated in the agriculture and service sectors. In 2060, agriculture will lose nearly 86 thousand FTEs in the low-emissions scenario, climbing to 274 thousand FTEs in SSP3-7.0, about 44 per cent of the sector's labour force. Services, often characterised by environments with limited climate control, ranks second, with losses escalating from 87 thousand to over 270 thousand FTEs across the scenario range. Construction shows comparable patterns (24,432-76,762 FTEs). Manufacturing, where small workshops often lack adequate cooling, will lose 23-73 thousand FTEs, while transport and trade are expected to record up to 43 thousand FTE losses. Finally, FTE losses in mining and quarrying will range from 2.8 to 9.2 thousand, a smaller impact owing to mechanisation and limited labour market size. Therefore, implementation of climate mitigation and adaptation policies will save more than 43,000 FTE jobs per year in agriculture, nearly 40,000 FTE jobs in services, as well as about 30,000 FTE jobs in the other industrial sectors (Infographic 3).

Table 5. Projected annual impact of rising heat stress due to climate change during 2040 on full-time equivalent jobs lost (proxied from work hours lost) in each sector of economic activity and across the different SSPs, calculated as the change between 2040 and the reference historical period 1985-2014.

Sector	2040	Available Work Hours (n)	Change in Work Hours		Change in Jobs (FTE)
			(n)	(% FTE)	
Agriculture	SSP1-2.6	1,258,068,240	-91,605,956	-7.28	-45,666
	SSP2-4.5		-139,554,964	-11.09	-69,569
	SSP3-7.0		-217,034,126	-17.25	-108,192
	SSP5-8.5		-134,893,553	-10.72	-67,245
Construction	SSP1-2.6	433,569,240	-27,338,403	-6.31	-13,628
	SSP2-4.5		-39,333,523	-9.07	-19,608
	SSP3-7.0		-63,527,315	-14.65	-31,669
	SSP5-8.5		-34,800,466	-8.03	-17,348
Manufacturing	SSP1-2.6	774,332,074	-25,524,545	-3.30	-12,724
	SSP2-4.5		-34,311,748	-4.43	-17,105
	SSP3-7.0		-57,246,558	-7.39	-28,538
	SSP5-8.5		-32,465,818	-4.19	-16,184
Mining and Quarrying	SSP1-2.6	76,395,651	-3,059,951	-4.01	-1,525
	SSP2-4.5		-4,598,505	-6.02	-2,292
	SSP3-7.0		-7,398,108	-9.68	-3,688
	SSP5-8.5		-4,483,157	-5.87	-2,235
Services	SSP1-2.6	2,974,456,234	-95,947,832	-3.23	-47,830
	SSP2-4.5		-138,056,610	-4.64	-68,822
	SSP3-7.0		-226,648,099	-7.62	-112,985
	SSP5-8.5		-125,023,551	-4.20	-62,325
Transport and Trade	SSP1-2.6	373,377,754	-14,403,916	-3.86	-7,180
	SSP2-4.5		-21,525,741	-5.77	-10,731
	SSP3-7.0		-34,775,915	-9.31	-17,336
	SSP5-8.5		-20,999,835	-5.62	-10,469
TOTAL	SSP1-2.6	5,890,199,194	-257,880,604	-4.38	-128,555
	SSP2-4.5		-377,381,091	-6.41	-188,126
	SSP3-7.0		-606,630,122	-10.30	-302,408
	SSP5-8.5		-352,666,381	-5.99	-175,806

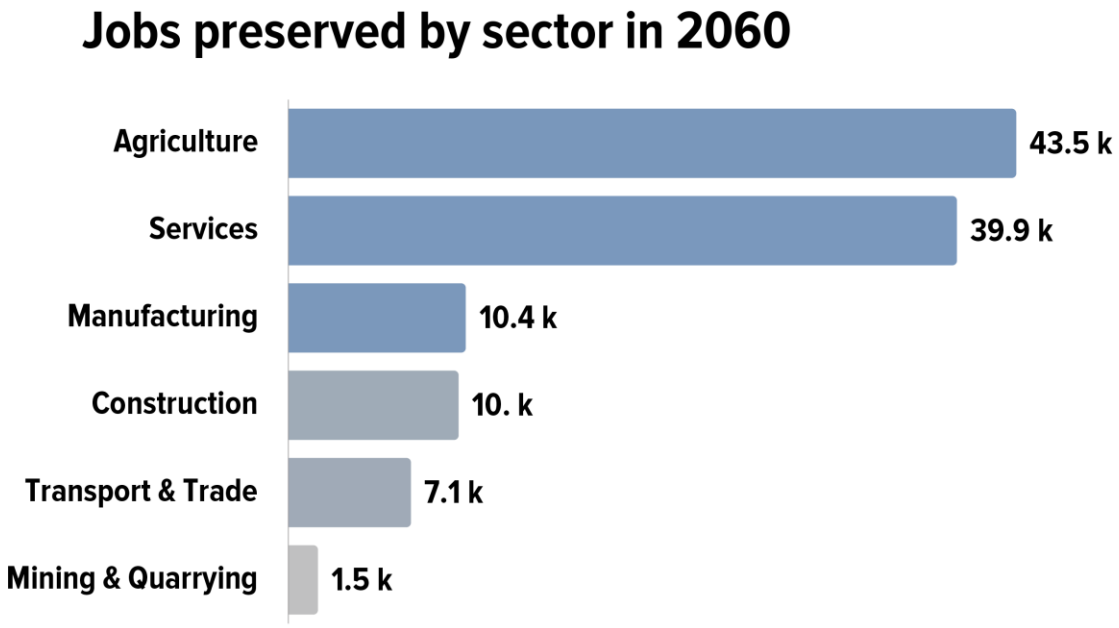
SSP: shared socioeconomic pathway; n: number; FTE: full-time equivalent.

Table 6. Projected annual impact of rising heat stress due to climate change during 2060 on full-time equivalent jobs lost (proxied from work hours lost) in each sector of economic activity and across the different SSPs, calculated as the change between 2060 and the reference historical period 1985-2014.

Sector	2060	Available Work Hours (n)	Change in Work Hours		Change in Jobs (FTE)
			(n)	(% FTE)	
Agriculture	SSP1-2.6	1,258,068,240	-172,588,087	-13.72	-86,036
	SSP2-4.5		-316,821,481	-25.18	-157,937
	SSP3-7.0		-549,981,005	-43.72	-274,168
	SSP5-8.5		-259,845,972	-20.65	-129,534
Construction	SSP1-2.6	433,569,240	-49,010,148	-11.30	-24,432
	SSP2-4.5		-82,325,405	-18.99	-41,040
	SSP3-7.0		-153,983,677	-35.52	-76,762
	SSP5-8.5		-68,995,716	-15.91	-34,395
Manufacturing	SSP1-2.6	774,332,074	-47,492,770	-6.13	-23,675
	SSP2-4.5		-80,638,662	-10.41	-40,199
	SSP3-7.0		-147,045,468	-18.99	-73,303
	SSP5-8.5		-68,343,146	-8.83	-34,069
Mining and Quarrying	SSP1-2.6	76,395,651	-5,681,819	-7.44	-2,832
	SSP2-4.5		-10,416,236	-13.63	-5,193
	SSP3-7.0		-18,530,673	-24.26	-9,238
	SSP5-8.5		-8,702,135	-11.39	-4,338
Services	SSP1-2.6	2,974,456,234	-174,217,294	-5.86	-86,848
	SSP2-4.5		-297,744,005	-10.01	-148,427
	SSP3-7.0		-541,856,257	-18.22	-270,118
	SSP5-8.5		-254,314,436	-8.55	-126,777
Transport and Trade	SSP1-2.6	373,377,754	-26,854,289	-7.19	-13,387
	SSP2-4.5		-48,904,179	-13.10	-24,379
	SSP3-7.0		-87,059,509	-23.32	-43,400
	SSP5-8.5		-41,093,774	-11.01	-20,485
TOTAL	SSP1-2.6	5,890,199,194	-475,844,406	-8.08	-237,211
	SSP2-4.5		-836,849,967	-14.21	-417,173
	SSP3-7.0		-1,498,456,589	-25.44	-746,987
	SSP5-8.5		-701,295,179	-11.91	-349,599

SSP: shared socioeconomic pathway; n: number; FTE: full-time equivalent.

Infographic 3. Sectoral labour market benefits of implementing in Senegal the decent work and sustainable development goals as described in SSP1-2.6, particularly in relation to workplace heat stress (calculated as differences between SSP5-8.5 and SSP1-2.6).



Policy messages emerging from the macro-economic analysis

- **Global mitigation matters**. The gap between SSP1-2.6 and SSP5-8.5 amounts to over 112 thousand saved jobs annually by 2060, underscoring the macro-labour dividend of achieving a 2°C climate goal.
- **Agriculture and services drive vulnerability**. Targeted adaptation, such as compulsory rest-break schedules and flexible hours as well as high-efficiency cooling retrofits and heat-resilient urban design will deliver the greatest employment protection. Fiscal incentives through energy-efficiency grants or concessional credit can accelerate uptake by small enterprises.
- **Recovery could amplify exposure**. As construction and tourism rebound, additional workers will move into heat-prone roles. Embedding thermal-stress thresholds in labour codes, linking them to social-protection floors and strengthening labour-inspection capacity will be vital to safeguard productivity gains.

Integrating the above measures into Senegal's National Adaptation Plan and Decent Work Country Programme will help protect the labour market from escalating climate-driven workplace heat stress while sustaining inclusive economic growth.

6. Recommendations

6.1. Relevant international labour conventions ratified by Senegal

Senegal would be encouraged to intensify its efforts toward adapting to climate risks, particularly in safeguarding workers from extreme heat and other climate-related hazards. This vulnerability underscores the importance of adopting ILO Conventions that enhance workplace safety in evolving environmental conditions. Aligning with ILO's OSH Conventions will enable Senegal to better integrate climate-resilient practices in the workplace, helping to reduce productivity losses and health risks, particularly in heat-sensitive sectors such as agriculture and construction where workers are most exposed to heat stress.

To date, Senegal has ratified 43 ILO conventions and 1 Protocol, including all of the fundamental ones.[60] Also, key OSH conventions relevant to managing heat stress have been ratified by Senegal. These include:

- **Convention No. 155** (Occupational Safety and Health [OSH]), which mandates the establishment of policies to prevent occupational accidents and illnesses. This Convention establishes guidelines for comprehensive OSH policies, which could include adaptive measures such as risk assessments, worker training on heat-related illnesses, and safety protocols specifically designed for extreme weather events.

- **Convention No. 161** (Occupational Health Services), emphasizing the provision of occupational health services. This Convention ensures access to occupational health services capable of monitoring and managing health impacts from environmental factors, and would reinforce Senegal's public health adaptation strategies.

- **Convention No. 187** (Promotional Framework for OSH), which encourages the continuous improvement of national OSH systems. This Convention enables continuous improvement of national OSH systems, supporting the ongoing integration of climate adaptation into health and safety standards.

In the coming years, Senegal should integrate climate adaptation measures within existing OSH frameworks to protect workers from increasing heat stress. Given its susceptibility to climate change and the projected rise in heat stress, as demonstrated in the present study, the above and other ILO Conventions would play a crucial role in managing heat-related risks. Drawing on the above Conventions for Senegal's OSH policies can also strengthen national resilience by promoting regular workplace risk assessments and updating safety protocols to address rising heat levels. Such measures can help Senegal prepare for projected increases in heat stress and other climate-related risks, contributing to a safer and more resilient working environment.

Furthermore, these OSH Conventions align with Senegal's broader climate and development objectives. Integrating OSH standards into climate adaptation efforts supports Senegal's commitment to the Paris Agreement by fostering a just transition for workers, enhancing the country's resilience to climate impacts, and reinforcing both worker protections and economic stability.

[60] https://normlex.ilo.org/dyn/nrmlx_en/f?p=1000:11200:0::NO:11200:P11200_COUNTRY_ID:103013

6.2. Policy recommendations for climate adaptation

To enhance its climate resilience and protect worker health, Senegal could consider further aligning its climate adaptation policies with ILO OSH standards. Adopting these standards would establish a comprehensive framework for addressing heat stress and other climate-related occupational hazards, particularly in sectors most vulnerable to heat, such as agriculture, construction, and services. This alignment with ILO OSH standards includes:

1. **Development of National Heat-Stress Guidelines:** Senegal is encouraged to work towards establishing national heat stress guidelines that align with recent ILO recommendations[1] on the prevention and mitigation of heat stress in the workplace, as also indicated in Convention No. 161 (Occupational Health Services), emphasizing the provision of adequate health services for workers. These guidelines should adopt the general OSH protection framework for heat stress recommended by the ILO[1] that includes, as a minimum standard, the following 10 basic protection requirements (grouped based on ILO's hierarchy of controls; also illustrated in Infographic 4):

   - **Risk Assessment:**

   1. Participatory risk assessment in the working environment integrating excessive heat.
   2. Use of the WBGT as a potential heat stress indicator to assess the level of heat exposure, with varying safety thresholds based on work intensity.

   - **Engineering Controls:**

   3. Provision of cool, shaded, and ventilated rest areas.

   - **Administrative Controls:**

   4. Identification of and targeted strategies for worker groups at high risk.
   5. Hydration strategies, including adequate sanitation facilities, especially for female workers.
   6. Rest, breaks or modified work schedules to limit or avoid exposure to excessive heat, including the ability to self-pace.
   7. Heat acclimatization measures for workers without recent heat exposure.
   8. Education and awareness on heat stress and heat-related illnesses.
   9. Regular medical check-ups and health monitoring.

   - **Personal Protective Equipment:**

   10. Personal protective equipment designed to protect workers from heat stress.

2. **Implementation of Regular Monitoring and Risk Assessments:** Senegal is encouraged to incorporate continuous monitoring and risk assessment protocols in workplaces, guided by Convention No. 187 (Promotional Framework for OSH). This would involve employers conducting regular assessments of workplace conditions using, preferably, the WBGT index, to evaluate heat stress levels and assess the effectiveness of heat mitigation measures. Additionally, employers should be encouraged to provide regular updates on worker exposure, health risks, and preventive measures, ensuring transparency and accountability in managing workplace heat hazards.[1]

3. **Role of Employers in Minimizing Heat-Related Hazards:** Employers should be encouraged to implement preventive measures for minimizing heat exposure risks. This should include, at a minimum, the development of a nation-wide early warning system, modified work hours during extreme heat, access to cooling solutions, and training for both employers and workers on identifying and responding to heat-related illnesses. Aligning with ILO's Decent Work Agenda, these measures would enhance

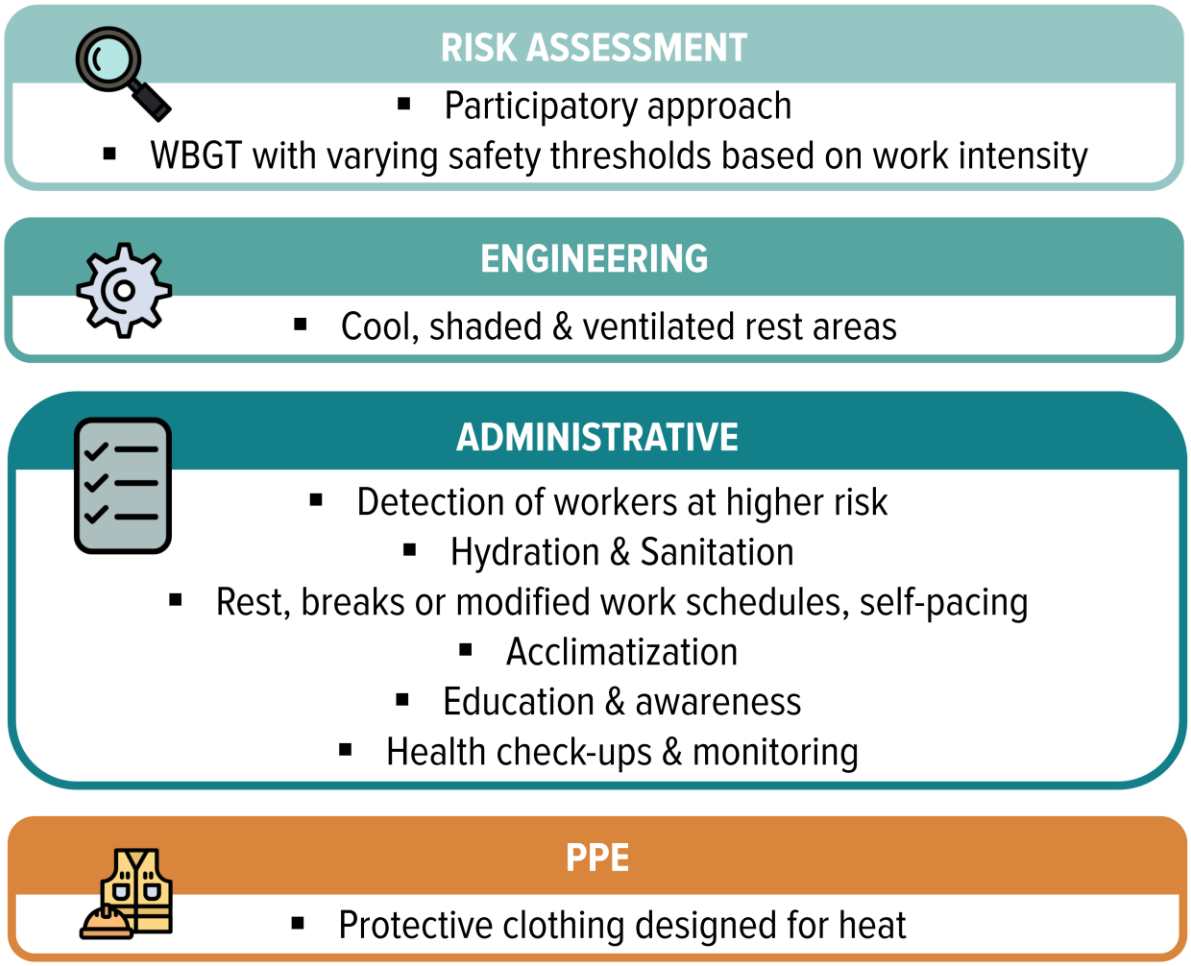
working conditions and uphold workers' rights to a safe and healthy workplace, particularly critical in Senegal's agriculture and construction sectors, where exposure to high heat exposure is frequent.

4. **Integration of Heat Stress into National OSH Policies:** Senegal is encouraged to explicitly incorporate heat stress as a key occupational hazard in its OSH policies, following ILO guidance on climate-responsive OSH frameworks. Policies should include minimum heat safety standards, mandatory reporting of heat-related incidents, and guidelines for high-risk sectors. Additionally, adopting national standards on emergency preparedness for extreme weather events would support worker protection in times of intense heat, aligning with ILO recommendations on OSH practices in a changing climate.[1]

5. **Promotion of Workplace Health Services and Support Systems:** Ensuring that all workplaces provide occupational health services that can monitor, advise, and treat workers affected by heat exposure is essential for worker safety. As per ILO Convention No. 161, access to these services should be mandatory in Senegal, particularly in sectors most vulnerable to heat stress. It is important that Senegal's health services include regular check-ups for workers, first aid for heat-related incidents, and preventive health programs focused on adapting to high-temperature work environments.[1]

6. **Utilization of social security funds to incentivise OSH and workplace heat stress adaptation:** Social security funds can be leveraged as an active policy instrument to incentivise OSH compliance and workplace heat stress adaptation. One potential approach is to introduce temporary reductions or suspensions of employer contribution rates, conditional on the verified implementation of workplace adaptation measures, such as cooling infrastructure, modified working hours, improved ventilation, or the provision of appropriate protective equipment. Foregone contributions could be recovered gradually over time, once adaptations are in place and operational. Such mechanisms can support employer cash flow in the short term, enabling necessary investments in workplace heat stress prevention and broader OSH improvements, while contributing to a reduction in work-related injuries and heat-related illnesses over time. In the medium to long term, this can generate savings for social security systems through lower benefit claims, reduced absenteeism, and improved labour productivity. By acting as preventative investors, social security funds can help shift OSH policy from a reactive to a preventive model. Temporarily lowering employer contributions in exchange for demonstrable risk-reducing measures creates financial incentives for enterprises to invest in safer and more resilient workplaces. These early-on incentives can significantly reduce future liabilities for social security administrations by lowering the incidence of occupational injuries, diseases, and disability claims. Overall, this approach aligns employer incentives with long-term system sustainability. Employers benefit from improved liquidity to upgrade workplaces, workers benefit from safer and healthier working conditions with reduced workplace heat stress risk, and social security systems benefit from improved financial sustainability through a healthier and more productive workforce.

Infographic 4. Decent work protection package for workplace heat stress, based on ILO's 10 basic protection requirements (grouped based on the hierarchy of controls).



By implementing the above ILO-aligned policy recommendations, Senegal can strengthen its climate adaptation efforts, create safer working conditions, and foster resilience among its workforce against climate change and rising heat stress. Moreover, implementing these recommendations will contribute to a sustainable, just transition in Senegal's labour market, in alignment with global labour and climate goals.

6.3. Key recommendations for climate adaptation per sector

Rising heat stress is already undermining worker health, productivity, and overall economic resilience in Senegal, with workers, enterprises, and the labour market each experiencing distinct pressures. Outdoor sectors such as construction, fishing, tourism, and farming face the highest risks, while indoor workers also struggle with poor ventilation and rising cooling costs. Vulnerable groups including women, migrant workers, and those in the informal sector experience disproportionate impacts due to limited protection, inadequate facilities, and unsafe working or living conditions.

Enterprises face reduced productivity, higher operational costs, and climate-related disruptions, while the wider labour market sees declining participation, increased precarity, and limited readiness to adapt. Overall, heat stress affects sectors and worker groups unevenly, underscoring the need for targeted, sector-specific and group sensitive interventions to ensure safe, fair, and sustainable working conditions. In light of the evidence presented in the present study, it is imperative to adopt sector-specific adaptation strategies that not only protect workers but also support continued economic activity. The following recommendations outline targeted

measures for each key economic sector, integrating the sector-specific vulnerabilities highlighted in earlier parts of the present study with practical, evidence-based adaptation strategies, ensuring that policy-makers and stakeholders have clear guidance on protecting workers and supporting economic stability in the face of rising workplace heat stress due to climate change. Importantly, these recommendations should be applied in addition to – not in place of – the general OSH protection framework for heat stress recommended by the ILO[1] which is described in Section 6.2. Collectively, the recommendations included in the present study provide a framework for tailoring climate adaptation measures to the unique challenges and opportunities within each economic sector. By implementing these strategies, Senegal can protect its workforce, sustain productivity, and enhance the resilience of its economy in the face of a warming climate.

The proposed measures emphasize the need for a comprehensive approach to managing workplace heat stress in the Senegalese workforce. Prioritizing the integration of workplace heat stress elements into the OSH framework, improving coordination among institutions, raising awareness, and building technical expertise are key steps. Short-term actions should focus on strengthening reporting and first-aid protocols, while long-term strategies call for a dedicated national OSH strategy on workplace heat stress and enhanced labour inspections. Together, these measures aim to protect workers, support enterprises, and ensure a resilient and safe labour environment.

Addressing workplace heat stress in the labour market requires effective coordination among multiple government institutions and private-sector actors. It is important to ensure that relevant authorities share a common understanding of workplace heat stress risks and work collaboratively to design and implement coherent responses. Establishing clear coordination mechanisms across these institutions is essential to avoid fragmented action and to ensure consistency in policy development, enforcement, and monitoring.

To support this process, a central coordinating body could serve as a national focal point and repository for information on workplace heat stress. This role could be supported by a dedicated inter-ministerial task force or working group responsible for monitoring ongoing initiatives, tracking progress, and facilitating coordination across sectors and levels of governance. Such a structure would strengthen oversight, enhance accountability, and enable more strategic allocation of resources.

Implementation should proceed in parallel at both the operational level (workplaces and communities) and the policy level. This dual approach will allow for practical, ground-level interventions to inform policy development, while enabling policy frameworks to support and scale effective local solutions. Establishing platforms for structured dialogue, promoting transparent data sharing, and fostering cross-sector partnerships among government, employers, workers' organisations, and civil society will be critical to developing practical, equitable, and sustainable strategies to manage workplace heat stress in Senegal.

Agriculture: In agriculture, where the majority of work is performed outdoors and workers are directly exposed to the natural elements, adaptation strategies should focus on minimizing heat exposure. These include adjusting work schedules to avoid the hottest parts of the day is essential, alongside implementing on-site measures such as the installation of shade structures, provision of adequate hydration, and cooling stations. Additionally, adapting crop management practices by shifting planting cycles and choosing heat-tolerant crop varieties can reduce the vulnerability of agricultural production to extreme heat. Worker training on recognizing the signs of heat stress and on implementing first-aid measures further enhances resilience in this critical sector.

Construction: Construction work is characterized by intense physical labour and significant exposure to outdoor heat. To protect construction workers, employers should consider rescheduling work to cooler periods, such as early mornings or late afternoons, and enforcing regular, scheduled breaks during the day. The deployment of portable shading, misting systems, and on-site hydration stations is critical to reducing workplace heat stress. Engineering controls, such as using reflective materials or temporary shade/insulation, can further mitigate the thermal load on construction sites. In addition, worker acclimatization programs and ongoing risk assessments are vital to ensure that adaptation measures remain effective as environmental conditions evolve.

Manufacturing: Manufacturing facilities, whether operating indoors or in partially exposed environments, must address both process-generated and environmental heat. Enhancing indoor climate control through improved ventilation and energy-efficient air conditioning systems is a key priority. Implementing structured work-rest cycles and staggered shifts can help manage cumulative heat exposure. In addition, installing real-time monitoring systems to track WBGT levels enables a proactive response to emerging heat stress risks. Employee

education and training on the importance of hydration and heat stress symptom recognition can further support a healthier and more productive workforce.

Mining and Quarrying: For mining and quarrying operations, which often occur in environments with high ambient temperatures or in confined underground spaces, robust environmental controls are crucial. Recommended actions include upgrading ventilation and cooling systems to maintain safer working conditions, as well as scheduling operations to reduce exposure during peak heat periods. Establishing mandatory rest breaks with access to cooled rest areas can help mitigate the physiological strain experienced by workers. Regular monitoring of WBGT, paired with comprehensive risk assessments, will ensure that protective measures are effectively tailored to fluctuating conditions. Where feasible, increased mechanization may reduce the need for direct human exposure to hazardous thermal conditions.

Services: Although the services sector is predominantly indoor, many subsectors (including retail, hospitality, and tourism) are vulnerable to heat stress, especially in facilities with inadequate climate control or in areas where outdoor work is required. Ensuring that workplaces are fitted with efficient cooling and ventilation systems, and that indoor temperatures remain within safe limits during heatwaves will safeguard workers' health and their productivity levels. Flexible scheduling and remote work options can also help mitigate risks for workers, particularly those performing heat-vulnerable jobs/tasks. In addition, service providers are encouraged to develop contingency plans and to conduct regular training and awareness campaigns about the risks of workplace heat stress. Such measures not only protect worker health but also support uninterrupted service delivery during periods of extreme heat.

Transportation and Trade: The transportation and trade sector, which encompasses both outdoor activities and logistics operations, faces unique challenges from heat stress. It is recommended that work schedules be modified to avoid extreme heat, with the establishment of climate-controlled rest areas and loading docks. Equipping drivers and logistics personnel with cooling equipment and appropriate personal protective gear will protect their health, reduce absenteeism, and safeguard uninterrupted service delivery. Moreover, infrastructural improvements, such as installing shading and misting systems at key transport hubs, can reduce heat exposure and maintain the efficiency of supply chains. These measures are critical to ensuring that the sector's operational continuity is not compromised by rising heat levels.

6.4. Role of the ILO's decent work agenda

Implementing the above-mentioned ILO-aligned policy recommendations and to advance the broader goals of the ILO Decent Work Agenda will generate important benefits for Senegal, as demonstrated in this study. This agenda aims to provide safe, productive, and fair working conditions, which are increasingly critical as Senegal faces heightened climate impacts, particularly rising heat stress levels. By adopting these measures, Senegal will strengthen its climate adaptation efforts, enhance workplace safety, and build resilience among its workforce against climate change and increasing heat stress. Furthermore, as shown below, adopting these measures will support a sustainable and just transition within Senegal's labour market, aligning with both global labour standards and climate objectives.

- **Promoting Safe and Healthy Workplaces in Senegal Amidst Rising Heat:** The Decent Work Agenda[61] prioritizes safe and healthy workplaces as essential for sustainable and equitable employment. For Senegal, implementing OSH Conventions such as Convention No. 161 (Occupational Health Services) establishes a solid framework for safeguarding workers in sectors particularly susceptible to extreme heat, including agriculture and construction. As highlighted in the present study, these sectors are crucial to Senegal's economy but are highly vulnerable to climate impacts, making the implementation of heat stress protections a pressing need. Establishing national heat stress guidelines and mandatory mitigation strategies aligns closely with the Decent Work Agenda's commitment to securing safe conditions across industries.[61]

[61] International Labour Organization. Decent work and the 2030 Agenda for sustainable development. Geneva, Switzerland (https://www.ilo.org/topics-and-sectors/decent-work-and-2030-agenda-sustainable-development).

- **Enhancing Productivity through Climate-Responsive OSH Measures:** Safe working conditions are essential to sustaining worker productivity, a core priority of the Decent Work Agenda.[61] Implementing heat adaptation strategies, such as structured work-rest cycles and hydration protocols, allows Senegal to minimize productivity losses due to heat stress.[1] These measures help maintain productivity levels during periods of intense heat, reducing economic disruptions and supporting a resilient labour market.[1] The Agenda's focus on fair and productive workplaces highlights the importance of addressing environmental risks that could jeopardize economic stability and workforce productivity.[61]

- **Focusing on Vulnerable and Informal Workers:** Informal workers, particularly those in agriculture, construction, and other high-risk sectors, are especially vulnerable to climate impacts due to limited access to social protections and occupational safety measures.[1] The Decent Work Agenda promotes inclusive and fair working conditions, ensuring protections for vulnerable groups.[61] Applying OSH standards to address climate risks helps prevent these workers from being disproportionately affected by rising heat. By mandating workplace safety measures, Senegal can enhance both climate resilience and social equity, fostering safer work environments across all segments of its labour market.

- **Advancing Social Protection and Fair Conditions:** The Decent Work Agenda emphasizes social protection as a cornerstone of fair and sustainable employment.[61] By implementing ILO OSH Conventions, Senegal can establish climate-responsive social protections, including health monitoring, emergency response services, and compensation for heat-related illnesses. This approach promotes equitable conditions amid climate challenges, aligning with the Agenda's commitment to secure and just employment for workers facing environmental stressors.[61]

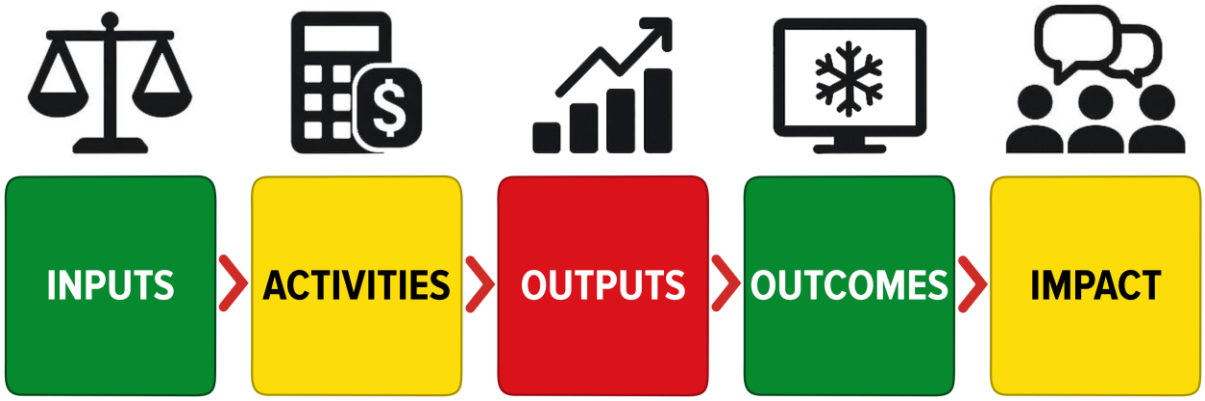
- **Contributing to Senegal's Just Transition to a Climate-Resilient Economy:** Incorporating the Decent Work Agenda into climate adaptation initiatives also aligns with Convention No. 187 (Promotional Framework for OSH), which encourages continuous improvement in national OSH policies. This framework is key to Senegal's just transition, supporting the development of a climate-resilient economy by fostering equitable and sustainable working conditions across all sectors. By embedding OSH standards within climate policies, Senegal can protect its workforce, ensuring that workers – especially those in high-risk sectors – are supported against the impacts of climate change and increasing heat stress.

In summary, designing future climate and environment policies in line with the ILO Guidelines for a just transition towards environmentally sustainable economies and societies for all will generate important public health, societal, and labour market benefits for Senegal. This will ensure that these policies will maximize the opportunities and minimize any challenges from the transition to a climate-resilient economy, including for workers in heat sensitive sectors. Coordinated efforts between the Government of Senegal, international organizations, and civil society are essential to ensuring that climate actions promote economic recovery and safeguard employment. Aligning climate adaptation strategies with the ILO Decent Work Agenda provides Senegal with a comprehensive approach to addressing climate impacts on labour, helping ensure that its workforce remains safe, productive, and resilient in the face of rising heat.

7. Scenario analysis to decent work and SDG implementation

Building on the findings described in Sections 2-5, scenario analysis was used to examine how full commitment to the ILO Decent Work Agenda and the 2030 Agenda for Sustainable Development could change Senegal's economic and labour-market trajectory under rising workplace heat stress. It follows the ILO results logic: inputs, activities, outputs, outcomes, and impact (Infographic 5). This framing is used across ILO programmes and guidance – including the Decent Work Agenda, the Just Transition Guidelines, and the Global Flagship Programme on Building Social Protection Floors – highlighting policy coherence and tripartite action as well as defining four pillars for decent work: employment, rights at work, social protection, and social dialogue.

Infographic 5. Decent Work theory of change for heat-safe work in Senegal: from inputs to impact.



Starting point

Heat is already costly. In 2023 GDP was 2.5 billion USD lower than the average year in 1985-2014 because of extra heat stress (Table 2). Services carried the largest absolute loss. Agriculture followed. Manufacturing and transport also declined. The same year the economy lost the equivalent of about 72 thousand full-time jobs. Losses cluster in and around Dakar and along main corridors. Rural districts show smaller absolute losses, yet the impact to household income can be large. These facts set the baseline for the scenarios in this section.

Quantified range from Section 5

By 2040 total GDP losses reach about 10.5 billion USD in a low-emissions world and 12.9 billion USD in a high-emissions world. By 2060 the range widens to 47.6 to 70.3 billion USD. The corresponding job-equivalent losses are about 129 thousand to 176 thousand FTEs in 2040. In 2060 the range is about 237 thousand to 350 thousand FTEs. Agriculture and services carry most of the toll in every case.

Theory of change for Decent Work and SDG implementation

Inputs. Political commitment to the four pillars of decent work (employment, rights, social protection, social dialogue). A legal base that embeds the right to a safe and healthy working environment and enforces OSH standards. Budgetary allocations and climate-finance inflows (e.g., for efficient cooling and heat-safe public spaces). Social protection floors with coverage for sickness, injury and income loss. Social dialogue with strong worker and employer voice. The ILO's Social Protection Floors Flagship Programme and the Just Transition Guidelines provide a ready set of tools for this work.

Activities. (1) implementation of ILO Conventions C155, C161 and C187; (2) adoption of a national heat-stress code of practice anchored in the 10 ILO protection requirements and the recommendations of Section 6 above

– the main pillar here is adopting and enforcing a national heat-stress standard based on WBGT with work-rest schedules, hydration, shade/ventilation, and acclimatisation provisions; (3) extension of social-protection floors to cover heat-related sickness, income protection and injury benefits for formal and informal workers; (4) shifting of public- and private-sector investment equal to 0.3-0.5% of GDP per year toward heat-safe, energy-efficient workplaces and public spaces (e.g., efficient cooling in schools, clinics and transport hubs; urban heat-island mitigation), and skills for green and heat-safe jobs; (5) addition of workplace heat stress to public procurement and building codes; (6) strengthening of labour inspection and tripartite social dialogue to co-design sector-specific practical protocols; and (7) establishing monitoring systems to track WBGT, lost work time, and heat-related illness.

Outputs. Rapid scaling of heat-safe worksites, wider coverage of social insurance, active programmes for green and resilience-oriented employment, practical guidance for high-risk sectors, better data on WBGT, lost time, and heat illness, as well as stronger labour inspection. These outputs reflect ILO practice under results-based management.

Outcomes. Fewer hours lost to heat. Lower injury, illness, and absenteeism. Better retention and productivity in agriculture, services, manufacturing and construction. Safer planting and harvesting windows. Fewer supply-chain delays at ports, markets and road hubs. Greater income security for women, migrants, and informal workers. These outcomes are consistent with the Decent Work Agenda and the SDGs (SDG8 on decent work, SDG3 on health, SDG13 on climate action).

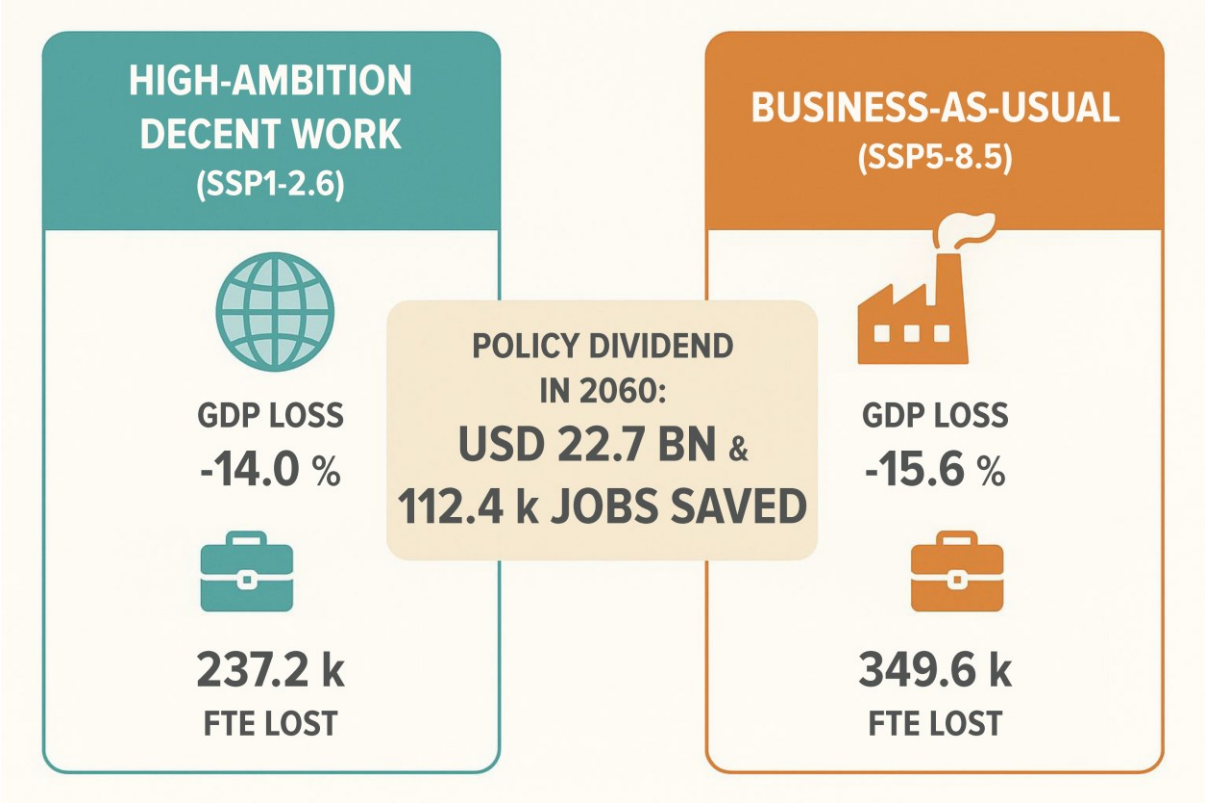
Impact. Higher effective labour supply. More stable GDP. Stronger resilience to shocks. A fairer transition. The ILO Just Transition Guidelines and the 2030 Agenda both place equity and dialogue at the centre of this change. Key results are summarized in Infographics 6-7.

- **Scenario A: High-Ambition Decent Work (Decent Work + SDGs implemented; climate consistent with SSP1-2.6).** Global emissions follow a Paris-consistent path. Domestically, Senegal implements the Decent Work package at scale. The country enacts a WBGT-based heat standard and enforces it. Employers provide shade, cool rest areas, safe water, and evidence-based breaks. Indoor sites improve ventilation and efficient cooling. Public works and procurement use heat-safe specifications. Social protection floors activate during heat alerts and cover medical care and income loss. Inspectors and social partners monitor compliance and update protocols. Under this scenario, Senegal's trajectory follows the lower bound of the projections in Section 5. GDP losses reach about **10.5 billion USD** in 2040 and **47.6 billion USD** in 2060. The economy still loses labour time, but far less than without action. Job-equivalent losses are close to **129 thousand** in 2040 and **237 thousand** in 2060. Services remain the largest source of absolute loss, yet productivity in retail, hospitality and public administration improves where cooling and scheduling are applied. Agriculture and construction benefit from earlier starts, strict work-rest cycles, and safer harvesting windows. Heat-safe skills and maintenance work grow. Access to social protection prevents harmful coping strategies and stabilises incomes of low-wage and informal workers. The risk of heat illness falls, which helps women and young workers who are over-represented in vulnerable roles. This path uses social dialogue to keep measures practical and fair. It also supports green growth and the just transition.

- **Scenario B: Business-as-Usual (fragmented uptake; climate consistent with SSP5-8.5).** Global emissions remain high. Uptake of Decent Work measures is piecemeal. There is no national heat standard based on WBGT. Enforcement is weak. Cooling investments lag in SMEs and public facilities. Social protection floors do not cover heat-related risks for all workers. Under this scenario Senegal moves toward the upper bound of the projections. GDP losses reach about **12.9 billion USD** in 2040 and **70.3 billion USD** in 2060. Job-equivalent losses rise to about **176 thousand** in 2040 and **350 thousand** in 2060. The service economy slows during hot months. Manufacturing faces frequent mid-day slowdowns and quality issues in small workshops. Construction accidents and stoppages increase.

Agriculture loses planting and harvesting hours during Q2 and Q3. Informal workers bear the brunt because they lack cooling, paid leave, and social insurance. Urban heat pushes site-level WBGT above safe thresholds more often. Without dialogue and inspection, compliance remains low and the benefits of isolated investments are not shared.

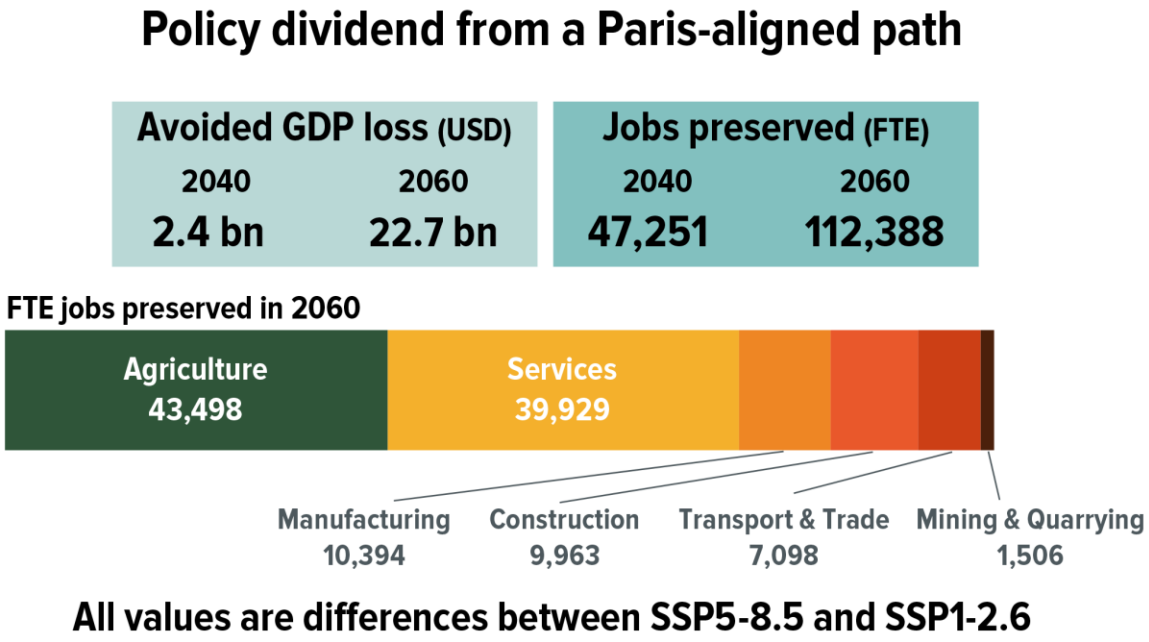
Infographic 6. Scenario analysis to decent work and sustainable development goal implementation in Senegal in relation to workplace heat stress. Figures calculated as differences between SSP5-8.5 and SSP1-2.6 based on the results presented in Section 5.



The policy dividend

Comparing the two scenarios shows the dividends from full Decent Work implementation in a low-emissions world. By 2040, avoided GDP losses are about **2.4 billion USD** each year and around **47 thousand FTE jobs** are preserved (Infographic 7). By 2060 the annual GDP benefit rises to roughly **22.7 billion USD**, and more than **112 thousand FTE jobs** are preserved. **Agriculture** and **services** capture the largest share of these benefits because they account for the bulk of current and projected losses (Infographic 7). In 2023 alone, heat stress already cut GDP by an extra 2.5 billion USD relative to the historical period. Services accounted for 970 million USD of that total, agriculture for 805.5 million USD, and manufacturing for 322.5 million USD. These losses compound over time through lower productivity and industrial competitiveness, and limited worker retention.

Infographic 7. GDP and labour market benefits of implementing the decent work and sustainable development goals in Senegal, particularly in relation to workplace heat stress. Figures calculated as differences between SSP5-8.5 and SSP1-2.6 based on the results presented in Section 5.



Qualitative pathways and distributional effects

Beyond economic and employment aggregates, Decent Work implementation changes the *quality* and *distribution* of outcomes:

- **Productivity and business continuity:** Heat-safe scheduling and efficient cooling reduce mid-day slowdowns and errors. Firms keep output steadier across seasons. The benefits are strongest in services and light manufacturing.
- **Health and OSH outcomes:** Lower WBGT exposure reduces heat exhaustion and dehydration. This cuts absenteeism and medical costs. The OSH system gains capacity by embedding occupational health services, as envisaged in ILO Convention C161.
- **Equity and informality:** Social protection floors targeted to heat alerts protect low-income workers, women, and migrants. Paid sick leave and emergency grants prevent income shocks. The Social Protection Floors Flagship Programme provides a tested model for this expansion.
- **Skills and jobs:** Training in efficient cooling, climate-smart agriculture, and heat-safe work methods create new jobs and upgrades existing ones. This supports a just transition as heat rises.
- **Governance and dialogue:** Tripartite dialogue aligns incentives and keeps standards workable. Labour inspection, data sharing and public procurement scale compliance over time. The ILO framework on OSH promotion and rights at work supports this institutional shift.

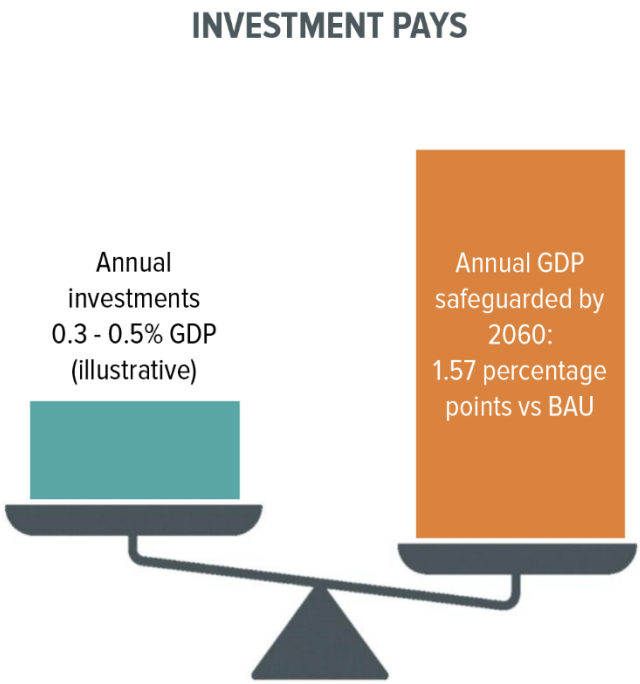
Implementation priorities

To realise Scenario A, three enablers are pivotal. First, embed **WBGT-based heat standards** in OSH regulation and public procurement and support them with labour inspection and worker participation. Second, extend **social protection floors** to cover heat-related sickness and income loss with simple triggers and rapid payment. Third, direct at least **0.3-0.5% of GDP per year in public and concessional finance to efficient cooling** in SMEs and public facilities, urban heat mitigation, shaded transport hubs and climate-smart agriculture. As shown in Infographic 8, even small annual investments directed toward implementing policies consistent with a Paris-aligned pathway (SSP1-2.6) will generate significant returns by 2060. **Progress should be tracked** against the

Section 5 baselines using three simple metrics: GDP safeguarded each year, FTE jobs preserved each year, and days above critical WBGT thresholds avoided. Additional activities are provided in Infographic 6.

The contrast between the two futures is stark. A high-ambition Decent Work and SDG pathway preserves output, protects workers and sustains inclusion. A business-as-usual path erodes labour capacity and compresses growth. Senegal can reduce the macro-economic burden of heat by combining international mitigation with a domestic Decent Work package centred on OSH, social protection, green investment and social dialogue.

Infographic 8. Investment case: cost vs returns of heat safe workplaces (calculated as difference between SSP5-8.5 and SSP1-2.6 based on the results presented in Section 5).



Based on the results of the present study, it is important to rapidly strengthen national readiness in Senegal to address workplace heat stress as a critical occupational, public health, and socio-economic challenge in the context of climate change and the national Just Transition agenda. A suggested timeline to implement the recommendations stemming from this study is presented in Infographic 9. To achieve this, several interrelated priorities should be set, from a policy and institutional development perspective, to develop a comprehensive National Workplan / Action Plan. This plan should aim to address workplace heat stress through a phased, multi-sectoral approach, translating the present findings and recommendations into concrete, time-bound, and implementable actions, supported by clear roles, responsibilities, and monitoring arrangements. The framework could comprise the following interlinked priority areas and actions:

1. **Strengthening the National OSH Framework:** The first priority is to strengthen the national OSH framework through the explicit integration of workplace heat stress into regulations, standards, and enforcement mechanisms. All heat-related risks should be clearly reflected in OSH legislation, policies, inspection protocols, and reporting systems, supported by clear definitions, thresholds, and procedures for reporting heat-related OSH incidents. In parallel, a formal inter-institutional coordination mechanism should be established to link relevant ministries, health authorities, environmental agencies, local councils, and other relevant stakeholders. This mechanism should support data sharing, enforcement coordination, early-warning systems, and emergency preparedness. Raising awareness of

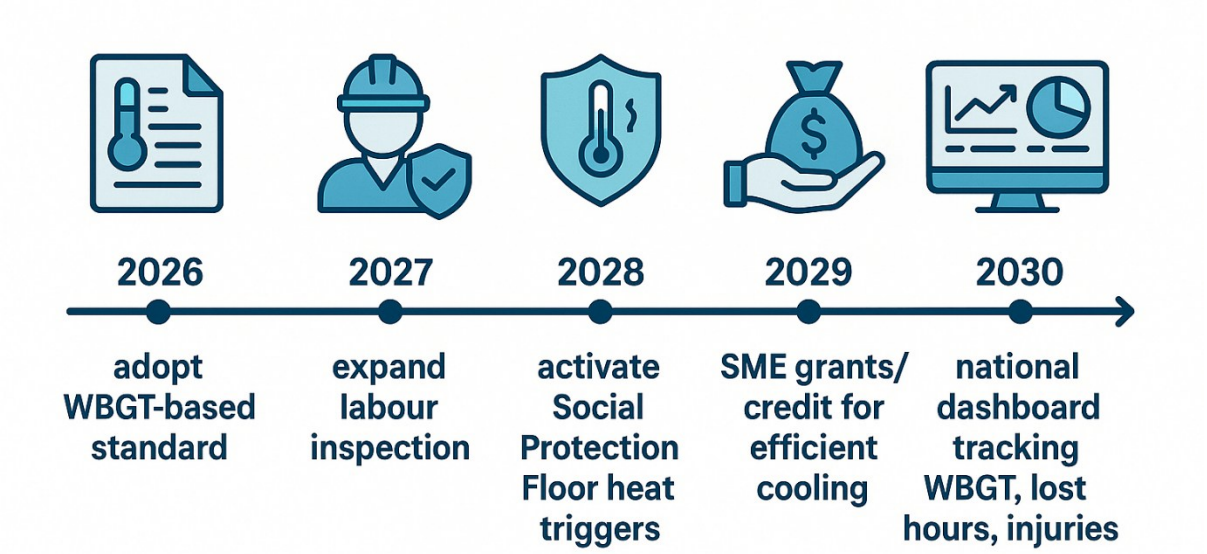
existing institutional frameworks is key, by improving understanding of institutional roles, responsibilities, and available OSH instruments among workers, employers, and communities. Moreover, it is essential to improve data availability and information flows, particularly to address gaps in the collection, consolidation, and sharing of data on heat-related injuries, sector-specific vulnerabilities, and geographic hotspots. Finally, good practices from frontline agencies should be documented and systematically integrated into OSH guidance, training programmes, and operational protocols.

2. **Capacity Building and Technical Expertise:** Building technical capacity is critical for effective implementation. Capacity-building initiatives in Senegal should strengthen expertise on workplace heat stress prevention, OSH compliance, climate-related risks, and Just Transition principles across government institutions, workers' organisations, and employers' organisations. Close collaboration with medical professionals is needed to improve the accuracy of reporting heat-related OSH injuries and illnesses, including linking health datasets with OSH surveillance systems. First-aid preparedness and training are key to ensure timely and effective responses to heat-related health events in workplaces.
3. **National Strategies and Regulatory Improvements:** There is a need to develop a "National Strategy on OSH and Workplace Heat Stress". This strategy should be supported by strengthened labour inspection capacity, enabling inspectors to assess workplace heat stress risks, enforce standards, and assist employers in mitigation planning. A comprehensive mapping of institutions and actors involved in workplace heat stress, OSH, environmental health, and social protection should be undertaken to clarify mandates and reduce fragmentation. OSH regulations should include specific provisions on workplace heat stress, clarifying sector-specific requirements, employer obligations, and worker rights. Policies should treat workplace heat stress as a cross-cutting issue, involving health authorities, urban planners, education institutions, and environmental agencies. New initiatives should build on existing policy frameworks to ensure coherence, avoid duplication, and promote broad stakeholder participation through whole-of-society approaches.
4. **Community-Level Measures and Social Inclusion:** Community-level measures are essential to complement workplace interventions. Outreach programmes should raise awareness among households, local businesses, and community leaders. Workplace heat stress awareness and adaptation practices should be integrated into school curricula and youth programmes. Active engagement of women, persons with disabilities, children, migrant workers, and other vulnerable groups is essential in both policy design and implementation. Preventive and response capacities within the health sector should be strengthened, including diagnosis, treatment, and public communication on heat-related illnesses. Workers' and employers' organisations should be actively involved in co-designing workplace policies, training materials, and sector-specific mitigation measures.
5. **Infrastructure, Urban Planning, and the Built Environment:** Climate-adaptive infrastructure and urban design can play important roles in addressing workplace heat stress in Senegal. This includes promoting climate-resilient construction materials, shading structures, improved ventilation, and adaptive designs. Urban greening policies should be strengthened, with clear requirements for shade, trees, landscaping, and green corridors, particularly in densely populated areas.
6. **Special Considerations for Densely Populated Areas:** Dedicated urban heat strategies should be developed for large urban areas, where heat exposure is intensified by high population density and limited green space. Research and promotion of clothing suitable for high-heat environments, particularly for outdoor and construction workers, should also be encouraged.
7. **Social Protection and Economic Measures:** Social protection mechanisms should be designed to support workers in sectors where productivity and working hours are reduced due to workplace heat stress. In this respect, it is important to consider anticipatory actions and forecast-based budgeting, linking climate forecasts with budget allocations, early warnings, and preventive measures. Workplace heat stress, labour-market impacts, OSH measures, and the protection of vulnerable workers should be explicitly integrated into Senegal's Third Nationally Determined Contribution implementation plans. Minimum living standards, particularly for migrant workers who are disproportionately exposed to heat risks, should be clearly defined and enforced. Research and analytical reports on climate change, heat

impacts, and economic implications should be made publicly available to support evidence-based policymaking.

8. **Social Protection and Economic Mental Health, Participation, and Policy Coherence:** The mental health impacts of workplace heat stress should be explicitly addressed within OSH and public-health frameworks. Health personnel should be adequately trained and equipped to manage increasing heat-related health burdens in the workplace. Environmental and climate awareness among local councils should be strengthened as part of decentralisation efforts. Workplace heat stress and OSH interventions should be aligned with the Sustainable Development Goals on health, decent work, climate action, and sustainable cities, as described in previous sections. Greening and shading initiatives should be prioritised equitably across all regions of the country.
9. **Governance, Transparency, and Early-Warning Systems:** Improving governance is essential for effective implementation. Environmental Impact Assessments should be strengthened to ensure that infrastructure and development projects are climate-resilient. Transparency and oversight mechanisms should be reinforced to support fair implementation of regulations and allocation of resources. An integrated ecosystem of information should be established, linking climate data, OSH incidents, health records, and labour statistics to support evidence-based decision-making. This should be complemented by SMS-based systems for heat alerts, early warnings, and public health advisories coordinated across ministries and local councils. Fair taxation systems and sustained political commitment should be considered to finance adaptation measures.

Infographic 9. Implementation timeline: a path to achieve heat-safe workplaces.



Next Step: Workplan Development and Tripartite Just Transition Strategy. As a first step in the above-described process, local stakeholders should jointly develop a comprehensive National Workplan / Action Plan. The plan should clearly define responsibilities, timelines, financing arrangements, and monitoring mechanisms for implementation. The ILO could provide technical support throughout this process. A potential effective way to initiate the workplan would be to convene a Technical Workshop to translate the agreed recommendations into a concrete, time-bound action plan addressing the impacts of rising temperatures on worker health and welfare, business operations and productivity, the national economy, and community resilience, within the framework of a tripartite Just Transition strategy.

8. Research limitations

While providing valuable insights, the analysis described in the present study is subject to technical limitations stemming from its methodology, data sources, and assumptions, which should be acknowledged in the context of Senegal's specific conditions.

One important limitation lies in the **modelling assumptions** used to estimate heat-induced work losses. The study applies a recently developed global labour loss function that links WBGT to the fraction of a work shift lost to heat exposure.[56] This function was derived from field studies across various countries and is calibrated for an "average, experienced, acclimatized worker" operating under typical conditions.[56] While this provides a robust general framework, it may not capture all nuances of Senegalese labour contexts. For instance, actual work-rest behaviours, acclimatization levels, and protective measures in Senegal could differ from the study's general assumptions. Moreover, the historical baseline chosen for analysis (1985-2014) is already approximately 0.75 °C warmer than pre-industrial times.[44] This means the projected climate-induced impacts in workplace heat stress are **conservative**, as some climate warming that has already occurred before the baseline is essentially "included into" the reference scenario. In effect, using a late-20th-century baseline avoids biases due to outdated work patterns but **underestimates the absolute impact of climate change** on heat stress by not accounting for pre-1985 warming. Policymakers should recognize that real-world impacts could be larger if referenced to true pre-industrial conditions.

Another set of limitations arises from the **data sources and resolution** used in the analysis. Owing to sparse localized data, the study relies on global datasets and model outputs that have been downscaled or resampled for Senegal. Climate variables (temperature, humidity, etc.) were taken from a single global climate model and downscaled to a grid of about 5 km, then aggregated for analysis (see Annex 1). Other key datasets (population, economic output, etc.) were available at coarser resolutions (~25 km) and likewise had to be interpolated or merged. While these steps ensure consistency across data layers, they inevitably **smooth over local variability**. Senegal's complex terrain and microclimates – from cooler higher altitude areas to hotter, humid coastal cities – may not be fully captured by grid-averaged climate data. Small geographic "hotspots" (for example, inner-city districts with urban heat island effects or particular valleys with extreme conditions) could, therefore, be under-represented. Similarly, using national or gridded averages for labour and economic activity can mask differences in heat exposure within sectors or regions. The model distributes impacts based on generalized population and sector data rather than detailed local employment patterns, so the **spatial distribution of losses** should be viewed as indicative rather than exact. Furthermore, there are **coverage gaps in labour data**, especially regarding informal employment. Official statistics and economic output data likely undercount informal and unregistered workers, who represent a significant proportion of Senegal's workforce. These workers are often in heat-exposed sectors such as agriculture, construction, or street trade, yet their productivity losses may not fully translate into the formal GDP metrics adopted in the present study. As a result, the projections may **underestimate total work hours lost and economic costs**, since any heat-stress impact on the sizable informal sector is not rigorously captured by formal data. In essence, data limitations mean that the findings paint a broad picture rather than a granular one, and actual on-the-ground impacts could diverge in specific locales or sub-populations.

The **climate projection scenarios** used in the present study also introduce technical caveats. The analysis focuses on four SSP scenarios (SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5) to represent a range of future greenhouse-gas emission pathways. These SSPs are global storylines and serve as useful proxies for low, moderate, and high warming futures, but they are not tailor-made for Senegal. In reality, Senegal's future emissions and development path may not neatly correspond to any single SSP. Senegal's outcomes could fall between scenarios or follow a different trajectory. Moreover, by necessity only a subset of possible scenarios was analyzed. Intermediate pathways (for example, scenarios reflecting uneven development or delayed mitigation beyond those chosen) were not explicitly modeled, meaning that the **full uncertainty range** of climate outcomes is not captured. A related limitation is that the study's climate projections are based on a **single climate model** (UKESM1-0-LL) for temperature and humidity. While this model was high-resolution and is a state-of-the-art choice, relying on one model's output means that the results do not reflect inter-model variability. Different climate models can project somewhat different patterns of warming, humidity, or extreme heat days for Senegal. By using one model, the analysis assumes its simulation is representative, but if that

model underestimates (or overestimates) future heat extremes in Senegal, the projected work productivity losses would be skewed accordingly. In addition, the climate data were handled at a monthly time scale. This captures long-term warming trends well, but may not fully account for **short-term heatwaves or day-to-day extremes** that can sharply impact work capacity. Any sub-monthly variability and the potential for consecutive extremely hot days (which can compound stress on workers) are largely averaged out in the scenario data. Therefore, while the SSP-based projections give a credible envelope of future conditions, one should bear in mind that **scenario and model choices** introduce uncertainty. The actual climate impact on Senegal could be somewhat higher or lower than depicted, especially if unmodeled extremes or divergent regional climate changes occur.

There is also **uncertainty in the workability and productivity response functions** when applied to Senegalese conditions. The physiological model underpinning the work-hour loss estimates is grounded in empirical studies, but these studies have inherent variability and may not include all the circumstances present in Senegal's labour force. For example, the response function assumes a given relationship between WBGT and the need for rest, based on an average worker sample. In practice, Senegalese workers' ability to cope with heat can vary with factors such as age, health status, type of work, and cultural practices (e.g. timing of work shifts or rest periods). The analysis does not explicitly differentiate how a young, healthy construction worker might tolerate heat versus an older agricultural worker or a street vendor with limited shade. This one-size-fits-all function means that **individual and subgroup differences** are not captured, as some workers may experience greater productivity loss than predicted, while others less. Moreover, the model presumes **current levels of acclimatization and work routines remain constant in the future**. It does not account for potential adaptation measures by workers or employers in response to rising heat (such as shifting work hours to cooler times of day, improving hydration and rest breaks, or mechanization to reduce physical strain). If such adaptations become common, they could mitigate some productivity losses, meaning the projected impacts might overstate what actually occurs. On the other hand, if extreme heat increases beyond physiological coping ranges, the simplistic linear response may understate losses for the hardest-hit days. While the present study provides uncertainty ranges (e.g. confidence intervals) around the estimated losses, these primarily reflect the statistical uncertainty in the empirical function and climate variability, rather than the full spectrum of **behavioural and physiological uncertainty**. In summary, users of the present study's results should recognize that the translation from heat levels to lost work hours is based on an idealized average response. Real-world outcomes could deviate if Senegalese workers' responses to heat stress differ from the model's assumptions.

Finally, the **estimation of WBGT and sectoral heat exposure** in this analysis involved necessary generalizations that limit precision. The WBGT for each location and sector was computed from meteorological data using a standard method (Liljegren's approach) with set parameter assumptions. For instance, **indoor working conditions** are modeled by assuming no direct solar radiation and a modest, fixed air movement of 1 m/s (to mimic light ventilation or fans). Indoor temperature and humidity were estimated as a function of outdoor conditions without accounting for building-specific cooling or insulation. In reality, indoor environments in Senegal vary widely. Some offices or facilities are air-conditioned (keeping WBGT lower than outdoor), while in other workplaces without cooling, heat can build up more than the model's simple ratio may predict (especially during power outages or in poorly ventilated spaces). Likewise, **underground or enclosed worksites** (e.g. any mining or tunnel operations) were approximated from surface weather data, which may not fully reflect actual thermal conditions underground where geothermal heat and ventilation play a role. The exposure assumptions also treat entire sectors uniformly in terms of work setting. For example, the agriculture and construction sectors were considered mostly outdoors (hence directly exposed to ambient heat), whereas sectors such as services or manufacturing were treated as predominantly indoor. In a Senegalese context, this generalized approach may be an oversimplification. Within services, a tourism worker guiding tours outside faces different heat stress than a bank employee inside an air-conditioned branch, yet both are counted under "services." Even within outdoor sectors, micro-environmental differences (working in shade versus sun, use of protective clothing, etc.) are not distinguished. Consequently, the **sector-level results should be interpreted as averages**, as actual heat exposure and productivity loss can vary within a sector based on specific job roles and locales. Moreover, because the analysis aligns workers with grid-cell climate data (using population distributions and national economic data), any mismatch between where people live versus where they work could introduce minor errors. For example, if many workers commute from cooler highlands to hotter coastal workplaces, the model may underestimate their exposure by tying them to home location climate. These granular issues are inherent in a

nationwide modeling study and highlight that the findings are **indicative trends subject to these aggregation effects**.

In conclusion, while the present study's projections of climate-induced workplace heat stress impacts on jobs and productivity in Senegal are grounded in the best available science and data, they remain constrained by the above technical factors. The use of global models and datasets, necessary assumptions about worker behaviour and sectoral exposure, and scenario uncertainties all mean the results are **approximate and conditional**. These limitations do not undermine the overall message that workplace heat stress poses a serious and growing challenge to Senegal's labour productivity, but they do delineate the **bounds of confidence** for the numbers presented. Policymakers and stakeholders should thus view the quantitative estimates as **guidelines within an expected range** and complement them with local observations and knowledge. A transparent understanding of these technical caveats will ensure that decisions and strategies informed by the present study properly account for its scope and the uncertainties in projecting climate change impacts on Senegal's workforce. This nuanced interpretation will help ground policy responses in realism, neither underestimating the threat of workplace heat stress nor overextending the precision of modelled forecasts.

Annex 1 – methodology

A1.1. Calculation of WBGT

For the calculation of the WBGT, the approach of Liljegren[62] was adopted because it is considered the most accurate method when calculating WBGT from meteorological data.[63] The environmental temperature, relative humidity, and wind speed data required for the calculation of WBGT were obtained from the relevant historical and SSP datasets provided in Section A1.2. Wind speed was corrected for height above the ground using previous methodology.[64] Solar radiation was estimated[65] for the midday of the middle day of each month using the geolocation (longitude and latitude) of each grid cell, while correcting for cloud coverage using published literature.[66] For indoor conditions, solar radiation was considered negligible, while wind speed was kept constant at 1 m/s, as this velocity is more indicative of the occupational settings where some air movement is generated by workers while they walk or move in the worksite.[63] Indoor temperature and humidity were estimated as a function of outdoor conditions.[67] Similarly, for the mining industry, underground temperature[68] and humidity[69] were estimated as a function of surface conditions.

A1.2. Datasets and Methodology

The present analysis included a collection of global datasets from recognized sources outlined in the following sub-Sections, including historical and projected data on population counts, global terrain elevation, climate, emissions, economic activity and demographics. Each dataset adopted different resolution and format, requiring resampling. Climate data were resampled to a target resolution of 3 arc minutes (0.05 degrees, 7200 longitude x 3600 latitude), while other datasets were resampled to 15 arc minutes (0.25 degrees, 1440 longitude x 720 latitude) using Python-based tools. This ensured consistent alignment across datasets for accurate merging and analysis.

A1.2.1. Population Datasets

Historical population data from the GPWv4 dataset,[70] covering the years 1990, 1995, 2000, and 2005, was obtained at a 15 arc-minute resolution. This dataset was already aligned with the target resolution and contained important information related to grid cells, including country mapping and land-water areas and it was used as the reference dataset for subsequent analysis.

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[62] Liljegren J.C., Carhart R.A., Lawday P., Tschopp S., Sharp R. (2008). Modeling the Wet Bulb Globe Temperature using standard meteorological measurements. Journal of Occupational and Environmental Hygiene; 5(10): 645-655.
[63] Lemke B., Kjellstrom T. (2012). Calculating Workplace WBGT from meteorological data: a tool for climate change assessment. Industrial Health; 50(4): 267-278.
[64] Masters, G.M. (2013). Renewable and efficient electric power systems. John Wiley & Sons.
[65] Khatib T., Elmenreich W. (2016). Modeling of photovoltaic systems using Matlab: Simplified green codes. John Wiley & Sons.
[66] Kasten F., Czeplak G. (1980). Solar and terrestrial radiation dependent on the amount and type of cloud. Solar Energy; 24(2): 177-189.
[67] Lee K, Lee D. (2015). The relationship between indoor and outdoor temperature in two types of residence. Energy Procedia; 78: 2851-2856.
[68] Yi, X., Ren, L., Ma, L. et al. (2019). Effects of seasonal air temperature variation on airflow and surrounding rock temperature of mines. International Journal of Coal Science and Technology; 6: 388–398.
[69] Yasidu U.M., Fujii Y., Kodama J.I., Fukuda D., Maneya G.J., Dandadzi J., Dassanayake A.B. (2019). Influences of water vapor on roof fall accidents in selected underground coal mines in Malawi. Advances in Civil Engineering; 2019(1): 5350686.
[70] Center for International Earth Science Information Network - CIESIN - Columbia University, Gridded Population of the World, Version 4 (GPWv4): Population Count, Revision 11. 2018, NASA Socioeconomic Data and Applications Center (SEDAC): Palisades, New York.

Population projections datasets, based on the SSP1, SSP2, SSP3, SSP4, and SSP5 were obtained from standard sources.[71,72] These projections were originally available at a resolution of 7.5 arc minutes (0.125 degrees 2880 longitude and 1440 latitude) and required resampling to 15 arc minutes. The process was performed using the rasterio library, applying the "Resampling.sum" method to aggregate population data across the new grid cells.[73] After resampling, datasets for rural, urban, and total populations were merged for the years 2010 to 2100, in 10-year increments.

A1.2.2. Global Terrain Dataset

The global terrain data from the GEBCO terrain model[74] was used. The data was initially provided at a resolution of 15 arc seconds (86400 longitude and 43200 latitude), and it was averaged into 15 arc-minute grid cells. During this process, negative values representing undersea topography were excluded, focusing only on land elevations for merging with climate data.

A1.2.3. Climate Datasets

The CMIP6 climate historical and projection datasets, derived from the "UKESM1-0-LL" model under the "r1i1p1f2" experiment,[75] were downloaded using the CHELSA (Climatologies at High Resolution for the Earth's Land Surface Areas) Python library. This library provides downscaled climate data estimates at a horizontal resolution of 30 arc seconds.[76,77,78] To ensure compatibility and facilitate computational efficiency, the datasets were upscaled to a target resolution of 3 arc minutes (0.05 degrees, 7200 x 3600 grid). Monthly data from the "UKESM1-0-LL" model was gathered for the following experiments: Historical, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5. The historical dataset spans 1985 to 2014, while the projection data covers 2020 to 2100. Specifically, near surface air temperature and near surface relative humidity, wind speed, maximum temperature, and total cloud cover percentage were obtained.

A1.2.4. Demographic Dataset

Hybrid gridded demographic dataset was obtained at resolution of 290 latitude by 720 longitude.[79] This demographic dataset contains fractional percentages for various age ranges, spanning from 5 to 65 years old. The data includes both historical and projected population distributions, covering the period from 1950 to 2050.

A1.2.5. Land Cover Dataset

The 2022 C3S Land Cover dataset (v2.1.1)[80] at 300-meter resolution was downloaded via the CDSAPI library, using lccs_class values to identify urban areas (class 190). A binary mask was created, assigning 1 to urban areas and 0 to others, and added to the dataset. The data was then resampled to a 15 arc-minute resolution by summing

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[71] Jones B., O'Neill B.C. (2016). Spatially explicit global population scenarios consistent with the Shared Socioeconomic Pathways. Environmental Research Letters; 11: 084003.
[72] Jones B., O'Neill B.C. (2020). Global one-eighth degree population base year and projection grids based on the Shared Socioeconomic Pathways, Revision 01. 2020, NASA Socioeconomic Data and Applications Center (SEDAC): Palisades, New York.
[73] Gillies S. et al. (2013). Rasterio: geospatial raster I/O for Python programmers. Mapbox.
[74] GEBCO Bathymetric Compilation Group. The GEBCO_2023 Grid - a continuous terrain model of the global oceans and land. 2023, NERC EDS British Oceanographic Data Centre NOC.
[75] Copernicus Climate Change Service (C3S). CMIP6 climate projections, in Climate Data Store (CDS). 2021.
[76] Karger D.N., Conrad O., Böhner J., Kawohl T., Kreft H., Soria-Auza R.W., Zimmermann N.E., Linder H.P., Kessler M. (2017). Climatologies at high resolution for the earth's land surface areas. Scientific Data; 4: 170122.
[77] Brun P., Zimmermann N.E., Hari C., Pellissier L., Karger D.N. (2022). Global climate-related predictors at kilometre resolution for the past and future. Earth System Science Data Discussions; 2022, 1-44.
[78] Karger D.N., Chauvier Y., Zimmermann N.E. (2023). chelsa-cmip6 1.0: a python package to create high resolution bioclimatic variables based on CHELSA ver. 2.1 and CMIP6 data. Ecography; 2023(6): e06535.
[79] Chambers, J. (2020). Hybrid gridded demographic data for the world, 1950-2020 (1.0), in Zenodo.
[80] Copernicus Climate Change Service (C3S). (2019). Land cover classification gridded maps from 1992 to present derived from satellite observation, in Climate Data Store (CDS).

the urban area cells using xarray's coarsen method.[81] A final dataset was produced with country-level details via geographical mapping, calculating each country's percentage of urban area grid-by-grid.

A1.2.6. Greenhouse Gas Emissions Datasets

Greenhouse gas emissions data were downloaded from the EDGAR datasets[82] and divided across four sectors:

- Agriculture sector, which included emissions from agricultural soils and enteric fermentation.
- Mining and Quarrying sector, which included methane emissions from natural gas extraction and processing.
- Manufacturing sector, which included emissions from chemical processes, industrial combustion, iron and steel production, solvent use, oil refining, and waste incineration.
- Transport and trade sector, which included emissions from aviation (landing and takeoff), road transportation, railways, pipelines, and off-road transport.

Each sector's emissions were aligned by latitude and longitude, summed, and resampled to a 15 arc-minute resolution. The emissions were then merged into a single dataset, indexed with sectoral and country-level details via geographical mapping. Finally, a new dataset was created to quantify each country's percentage contribution to emissions within each sector, calculated grid-by-grid.

A1.2.7. GDP Dataset

Country-level economic data on the structure of value added was obtained from the United Nations Statistics Division (Latest Data Upload: January 2025) for the period 1970-2023.[83] The dataset contains the contributions of various sectors, including agriculture, hunting, forestry, fishing (ISIC A-B), mining, manufacturing, utilities (ISIC C-E), manufacturing (ISIC D), construction (ISIC F), wholesale, retail trade, restaurants and hotels (ISIC G-H), transport, storage and communication (ISIC I), other activities (ISIC J-P), as well as total value added, to each country's GDP, expressed in constant 2015 USD.

In addition, a multi-country, multi-sector, multi-scenario gridded dataset of projected gross domestic product (GDP) was developed for the years 2040 and 2060. Historical sectoral GDP for each country was sourced from UN National Accounts,[84] and these values were spatially distributed to grid cells based on the emissions dataset. Future total GDP projections for each grid cell, scenario (SSP1–SSP5), and years (2040, 2060) were obtained from the Zenodo global gridded GDP dataset v7.[85]

For each country, the proportional contribution of each sector per grid cell was computed based on the distribution for the year 2023. These sectoral shares were then applied to projected total grid cell GDPs for 2040 and 2060 to estimate sector-specific GDP at each location under each scenario.

Future grid-cell and sector-level GDP values were initially expressed in purchasing power parity (PPP) international dollars. To enable cross-country comparison and economic analysis in nominal terms, the PPP-based GDP values were converted to market exchange rate (MER) GDP using country- and year-specific Price Level Ratios (PLR). The PLR for each country and scenario was extrapolated to 2040 and 2060 using a linear fit to World Bank historical PLR values (2000-2019).[86] The conversion was performed as follows: GDP_MER=GDP_PPP*PLR

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[81] Hoyer S., Hamman J., xarray: 1. Arias P, Bellouin N, Coppola E, et al. Technical Summary. In: Masson-Delmotte V, Zhai P, Pirani A, et al, eds. Climate Change 2021: The Physical Science Basis Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press; 2021. labeled arrays and datasets in {Python}. Journal of Open Research Software, 2017. 5(1).

[82] EDGAR Community GHG Database v8.0: CO2, CH4, N2O, and F-GASES, in European Commission, Joint Research Centre (JRC) and International Energy Agency (IEA). 2023.

[83] United Nations Statistics Division, Department of Economic and Social Affairs, Statistics Division - National Accounts (Latest Data Upload: January 2025). Value Added by Economic Activity, at constant 2015 prices - US Dollars.

[84] https://unstats.un.org/unsd/snaama/Basic.

[85] Wang, T., & Sun, F. (2023). Global gridded GDP under the historical and future scenarios [Data set]. Zenodo. https://doi.org/10.5281/zenodo.7898409.

[86] https://data.worldbank.org/indicator/PA.NUS.PPPC.RF.

A1.2.8. Employment Dataset

Economic activity data was obtained from ILOSTAT,[87] providing employment data across different economic sectors and genders. The 14 variables provided in the ILO dataset were divided into six sectors using the standard intermediate-level aggregation[88] as follows:

- Agriculture (ISIC rev.4: A).
- Mining and Quarrying (ISIC rev.4: B).
- Manufacturing (ISIC rev.4: C).
- Construction (ISIC rev.4: F).
- Transportation and Trade (ISIC rev.4: H, G).
- Services, which included all remaining activities: utilities (ISIC rev.4: D, E), accommodation and food service activities (ISIC rev.4: I), information and communication activities (ISIC rev.4: J), financial and insurance activities (ISIC rev.4: K), real estate; business and administrative activities (ISIC rev.4: L, M, N), public administration and defense (ISIC rev.4: O), education (ISIC rev.4: P), human health and social work activities (ISIC rev.4: Q), and other services (ISIC rev.4: R, S, T, U).

A1.2.9. Sector Distribution

Two datasets were used to calculate the distribution of each sector on each grid cell: the urban area land cover data (providing the percentage of urban area per grid cell; see A1.2.5) and the emissions data (including sectoral emission percentages; see A1.2.6). For the Agriculture, Mining-Quarrying, Manufacturing, and Transportation-Trade sectors, sectoral emission percentages were used from the above-mentioned emissions dataset as the distribution parameter within the grid cells, while urban area percentages were applied for the Construction and Services sectors.

In cases where the emissions dataset did not include information for mining in the country of interest, the Global Mines and Minerals dataset from the United States Geological Survey was utilized.[89] The original data consisted of point locations specified by latitude and longitude coordinates for various mining sites. To align with the target resolution of 15 arc minutes, the point data was transformed into grid cells. During this process, an equal distribution method was applied within each grid cell containing mining points.

Next, using the ILO employment dataset (with gender-specific employment counts), the number of male and female workers in each sector was calculated for each grid cell based on sectoral employment data and the percentage contribution from emissions or urban area. This process was repeated for all six economic activity sectors, with the final dataset containing estimated number of male and female workers per sector, indexed by latitude, longitude, sector, and country.

Similarly, for each grid cell, using the above-mentioned GDP dataset, the GDP by sector of economic activity was calculated based on the percentage contribution from emissions or urban area. This process was also repeated for all six sectors, producing a final dataset containing the estimated GDP in USD millions, indexed by latitude, longitude, sector, and country.

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[87] International Labour Organization (ILO). Employment by sex and economic activity -- ILO modelled estimates, Nov. 2023 (thousands) -- Annual, in ILO Modelled Estimates (ILOEST) Database. 2023, ILO, Geneva, Switzerland.
[88] United Nations Statistics Division, Department of Economic and Social Affairs (2008). International Standard Industrial Classification of All Economic Activities (ISIC) - Statistical papers, Series M No. 4/Rev.4. New York, USA.
[89] United States Geological Survey. Global Mines and Minerals dataset: https://mrdata.usgs.gov/mineral-operations. Accessed: October 1, 2024.

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