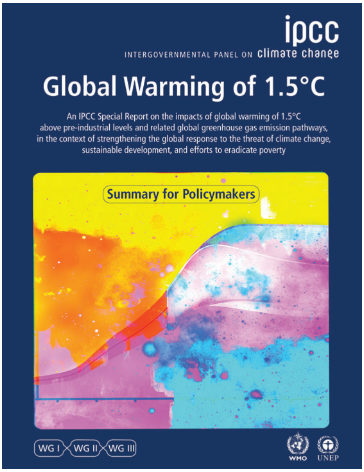

Summary for Policymakers IN BRIEF

This document is an attempt to make the SR15 Summary for Policymakers (SPM) more accessible, by reducing the text and presenting just the relevant information – especially the numbers – in clear, brief bullet form, but using as far as possible the wording as approved by governments.

Confidence statements, or uncertainty language, a vital part of the assessment, are omitted here to improve readability. Readers may check these details in the published SPM, which is available at https://www.ipcc.ch/sr15/chapter/summary-for-policy-makers/

Section lettering and numbering are the same as in the published SPM, allowing easy cross-referencing. The SPM contains references to the relevant chapters and sections of the full SR15 that support each statement. The report (https://www.ipcc.ch/sr15/) in turn cites the original source of the information. In this way readers may follow the trail of evidence from this summary document all the way back to the underlying literature.

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A. Understanding Global Warming of 1.5°C

A1 Global warming

- Human activities have caused global warming of 1.0°C (0.8 to 1.2°C)
- Global mean surface temperature is rising by 0.2°C per decade (0.1-0.3°C)
- Will reach 1.5°C between 2030 and 2052, at current rate
- Greater warming is observed in many regions and seasons
  - 2 to 3 times higher in Arctic
- Changes in weather extremes have been observed at 0.5°C of global warming
  - Greater changes expected with further warming

A2 Long-term changes

- Past anthropogenic emissions alone are unlikely to cause 1.5°C warming by 2100
- Reaching and sustaining net-zero emissions would halt global warming
- Maximum warming is determined by total sum of past, present and future CO_2 emissions, and by other greenhouse gas and aerosol in the decades prior to that point.
- Net-negative CO_2 emissions may be required to
  - Prevent further warming after 2100
  - Reverse ocean acidification
  - Minimize sea level rise

A3 Risks for natural and human systems

- Impacts have already been observed in human and natural land and ocean systems
- Future risks depend on
  - Warming (rate, peak, duration)
  - Geographic location
  - Levels of development and vulnerability
  - Adaptation and mitigation
- Risks are higher at 1.5°C than at present, and even higher at 2°C
- Risks are higher if temperature exceeds 1.5°C temporarily than if it is halted at 1.5°C
- Long-lasting or irreversible risks are possible if temperature peaks at 2°C
- Future risks would be reduced by
  - far-reaching, multilevel, cross-sectoral climate mitigation
  - incremental and transformational adaptation

B. Projected climatic changes, potential impacts and associated risks

B1 Climate change from 1°C to 1.5°C to 2°C

- Higher mean temperature in most land and ocean regions
- Hot extremes in most inhabited regions
  - Extreme hot days warm by 3 - 4°C in mid latitudes
  - Extreme cold nights warm by 4.5 - 6°C in high latitudes
  - Number of hot days increase, highest increase in tropics
- Decreased precipitation in several regions, with probability of drought and precipitation deficit
- Increased precipitation in several regions
  - Higher frequency, intensity, and/or amount of heavy precipitation
  - Higher precipitation associated with tropical cyclones
  - More land area affected by flooding

B2 Sea level rise

- Global sea level rise is 0.26-0.77m by 2100, at 1.5°C
  - 0.1m (0.04-0.16m) higher at 2°C
  - 10 million fewer people exposed than at 2°C (2010 population)
  - Slower sea level rise reduces risks and enables opportunities for adaptation
- Sea level rise continues beyond 2100, even at 1.5°C
  - Magnitude and rate depend on future emissions
- Multi-meter rise possible over hundreds to thousands of years
  - Due to Antarctic marine ice sheet instability and/or loss of Greenland ice sheet
  - Irreversible ice sheet instabilities could be triggered at 1.5 to 2°C
- Risks to human and ecological systems
  - In small islands, low-lying coastal areas, deltas
  - Increased salt-water intrusion, flooding, damage to infrastructure

B3 Biodiversity and ecosystems

- Species are projected to lose over half their climatically determined geographic range for
  - 6% of insects, 8% of plants and 4% of vertebrates at 1.5°C
  - 18% of insects, 16% of plants and 8% of vertebrates at 2°C

- Impacts from fires and invasive species are lower at 1.5°C than at 2°C
- Ecosystems are projected to change type for
    - 4% (2-7%) of global terrestrial land area at 1°C
    - 7.5% of global terrestrial land area at 1.5°C
    - 13% (8-20%) of global terrestrial land area at 2°C
- High-latitude tundra and boreal forests are at particular risk
- Permafrost thawing of 1.5-2.5 million km^2 less at 1.5°C than at 2°C

B4 Ocean temperature, acidity, oxygen levels

- Arctic sea-ice-free summer occurs at least once per century at 1.5°C
    - Once per decade at 2°C, effects reversible
- Species range shifts and damage to ecosystems
    - Coral reefs decline by further 70-90% at 1.5°C, and by >99% at 2°C
    - Increasing risk of irreversible losses, especially at 2°C or more
- Ocean acidification amplifies adverse effects of warming
    - Impacts on survival, calcification, growth, development, abundance of broad range of species
- Productivity loss in fisheries and aquaculture, especially around equator
    - Physiology, survivorship, habitat, reproduction, disease, invasive species
    - Loss of 1.5 million tonnes at 1.5°C in global annual catch for marine fisheries
    - Loss of >3 million tonnes at 2°C

B5 Human wellbeing

- Human health, livelihoods, food and water, security, economic growth at lower risk at 1.5°C than at 2°C
    - Disadvantaged, vulnerable populations, indigenous peoples, communities dependent on agriculture or coastal livelihoods are particularly at risk
    - Higher risks in Arctic, drylands, least developed and small island developing states
    - Increasing poverty and disadvantage, several hundred million fewer people at risk at 1.5°C than at 2°C
- Heat-related health risks (especially heat islands in urban areas)
- Ozone-related health risks depend on emissions
- Vector-borne diseases projected to increase and shift range, reaching new areas.
- Nutrition and food security, due to
    - Cereal crop yield losses and drop in nutritional quality, particularly sub-Saharan Africa, Southeast Asia, Central and South America

   - Reduced food availability, particularly in Sahel, southern Africa, the Mediterranean, central Europe, the Amazon
   - Livestock affected adversely from heat, feed quality, diseases, water scarcity
- Water stress to affect half as many people at 1.5°C than at 2°C, regionally variable
- Global economic growth at risk, largest impacts in tropics and Southern hemisphere subtropics
- Multiple and compound risks create new (and exacerbate current) hazards, exposures, and vulnerabilities
   - Exposed populations susceptible to poverty are greatest in Africa and Asia
   - Risks to energy, food, and water sectors could overlap spatially and temporally
- Reasons for Concern higher than assessed by AR5, at 1.5°C and 2°C
   - Unique and threatened systems: high to very high
   - Extreme weather events: moderate to high
   - Distribution of impacts: moderate to high
   - Global aggregate impacts: moderate to high
   - Large-scale singular events: moderate to high

B6 Adaptation: options and limits

- Adaptation can reduce risk and impacts
- Number and availability of options vary by sector, decline with greater warming
   - Natural and managed ecosystems: ecosystem-based adaptation, ecosystem restoration and avoided degradation and deforestation, biodiversity management, sustainable aquaculture, local knowledge and indigenous knowledge
   - Sea level rise: coastal defence and hardening
   - Human health and livelihoods: irrigation, social safety nets, disaster risk management, risk spreading and sharing
   - Urban areas: green infrastructure, sustainable land use and water management
- Challenges for adaptation high at 1.5°C, even higher at 2°C
   - Multiple interrelated risks in several vulnerable regions, small islands, least developed countries
- Limits to adaptation are more pronounced with greater warming, with implications for ecosystems and human health

C. Emission Pathways and System Transitions Consistent with 1.5°C Global Warming

C1 Mitigation: options and limits

- Global CO_2 emissions: deep reductions from 2010 levels
  - 45% by 2030, net-zero by 2050, for 1.5°C (with no/limited overshoot)
  - 25% by 2030, net-zero by 2070, for 2°C
- Mitigation portfolios balance lower energy and resource intensity, decarbonisation, and carbon dioxide removal
  - Different challenges, synergies and trade-offs with sustainable development
- Non-carbon emissions (methane, black carbon, cooling aerosols): deep reductions from 2010 levels
  - >35% or more reductions by 2050, from energy, agriculture, waste, industry
  - Improved air quality provides immediate, direct health benefits
  - Bioenergy demand can increase nitrous oxide emissions
- Carbon budget is being depleted by 42 ± 3 $GtCO_2$ per year. Remaining budget is:
  - 580 $GtCO_2$ for a 50% chance, or
  - 420 $GtCO_2$ for a 66% chance, of staying below 1.5°C global mean surface air temperature
  - Non-carbon emissions affect carbon budget by ±250 $GtCO_2$
- Uncertainties in carbon budget:
  - ±400 $GtCO_2$ due to climate response
  - ±250 $GtCO_2$ due to historic warming
  - +100 $GtCO_2$ due to permafrost thawing and wetland methane release
- Solar radiation modification face substantial limitations and do not deal with ocean acidification

C2 Systems transitions

- Limiting global warming to 1.5°C implies transitions that are rapid, far-reaching, unprecedented in scale
  - Deep emissions reductions, all sectors, wide portfolio, upscaling of investments
  - System changes more rapid, pronounced over next 20 years in 1.5°C than 2°C pathways

C. EMISSION PATHWAYS AND SYSTEM TRANSITIONS CONSISTENT WITH 1.5°C GLOBAL WARMING

C2 System transitions (cont.)

- Energy: lower demand, higher efficiency, faster electrification, low-carbon sources
  - For 1.5°C pathways with no/limited overshoot:
    - Electricity generation 70–85% from renewable sources by 2050
    - Increasing CO_2 capture and storage (CCS) for nuclear and fossil fuels
    - Gas reduced to 8% of electricity generation (with CCS)
    - Coal reduced to 0%
  - Solar / wind energy and electricity storage technologies show increased political, economic, social and technical feasibility
- Industrial CO_2 emissions: deep reductions
  - 65-90% reduction from 2010 level by 2050 for 1.5°C
    - 50-80% reduction for 2°C
  - Through electrification, hydrogen, sustainable bio-based feedstocks, product substitution, carbon capture, utilization and storage.
    - Options are technically proven, but deployment is limited by economic, financial, human capacity and institutional constraints
- Urban and infrastructure
  - Land use, urban planning, emissions reductions
  - Buildings:
    - 55–75% share of electricity demand by 2050 for 1.5°C
    - 50–70% share for 2°C
  - Low-carbon transport increases from <5% in 2020
    - to 35–65% in 2050 for 1.5°C
    - to 25–45% for 2°C
- Land use changes similar in 1.5°C and 2°C pathways
- Food / feed crops: from 4 million km^2 less, to 2.5 million km^2 more, of non-pasture agricultural land
- Pasture land: 0.5–11 million km^2 less
- Energy crops: 0–6 million km^2 more agricultural land
- Forests: from 2 million km^2 less, to 9.5 million km^2 more, relative to 2010
- Supported by sustainable management of demands on land for human settlements, food, livestock, fibre, bioenergy, carbon storage, biodiversity and ecosystem services
- Demand for land is reduced by sustainable intensification of land use practices, ecosystem restoration, less resource-intensive diets

- Barriers: socio-economic, institutional, technological, financial, environmental, with regional differences
- Energy-related investments in 1.5°C pathways:
  - 830 (150–1700) billion US$2010 extra per year
  - For supply, total investment (2016 to 2050): 1460 to 3510 billion US$2010
  - For demand, total investment (2016 to 2050): 640 to 910 billion US$2010
  - 12% (3–24%) higher than in 2°C pathways
  - Investment in low-carbon technology and energy efficiency is 6 (4–10) times higher in 2050 than in 2015
- Discounted marginal abatement costs
- 3 to 4 times higher than for 2°C pathways
- Total mitigation cost of 1.5°C pathways not assessed due to limited literature
- Knowledge gaps in integrated assessment of costs and benefits of mitigation

C3 Carbon dioxide removal (CDR)

- CDR used in all 1.5°C pathways
- 100–1000 GtCO_2 removal by 2100
  - To compensate for residual emissions, achieve net negative emissions
  - 1–12 GtCO_2 per year, starting now
- Existing CDR measures:
  - Afforestation, reforestation, land restoration, soil carbon sequestration
- Potential CDR measures:
  - Bioenergy with carbon capture and storage (BECCS)
  - Direct air carbon capture and storage (DACCS)
  - Enhanced weathering and ocean alkalization
- Agriculture, forestry and land-use based CDR
  - 0–5 GtCO_2 per year in 2030, 1–11 in 2050, and 1–5 in 2100
  - Potential / limit: 3.6 GtCO_2 per year
- Bioenergy with carbon capture and storage (BECCS)
  - 0–1 GtCO_2 per year in 2030, 0–8 in 2050, and 0–16 in 2100
  - Potential / limit: 5 GtCO_2 per year
  - Can be avoided through reduced demand and greater reliance on land use based CDR measures
  - Bioenergy requirements are higher without BECCS than with BECCS

C. EMISSION PATHWAYS AND SYSTEM TRANSITIONS CONSISTENT WITH 1.5°C GLOBAL WARMING

C3 Carbon dioxide removal (CDR) (cont.)

- Reversing 1.5°C overshoot relies on extra CDR
  - The larger the overshoot, the greater the need for CDR later
  - Limitations to CDR deployment exist (speed, scale, societal acceptability)
  - Uncertainty about how effective negative emissions are in reversing overshoot
- Trade-offs on land, energy, water, nutrients with large scale CDR
  - Afforestation and bioenergy can compete with food, biodiversity, ecosystems
- Co-benefits of restoration of natural ecosystems and soil carbon sequestration
  - Can improve biodiversity, soil quality, local food security
- Multiple options are more feasible than single option at very large scale
- Effective governance is needed to
  - Limit trade-offs
  - Manage CDR portfolios
  - Enable sustainable land management
  - Conserve and protect land carbon stocks, ecosystem functions and services

D. Strengthening the Global Response in the Context of Sustainable Development and Efforts to Eradicate Poverty

D1 Nationally stated mitigation ambitions

- Current Nationally Determined Contributions (NDCs) as per Paris Agreement are not enough to limit warming to 1.5°C
- NDCs (if met) would
  - Lead to 52–58 $GtCO_2eq$ emissions per year
  - Result in 3°C warming by 2100, more thereafter
- 1.5°C pathways show 40–50% reduction of emissions from 2010 level
  - Down to <35 $GtCO_2eq$ per year (25–30 interquartile range) by 2030
- Reversing overshoot of 0.2°C by 2100 requires levels of CDR that may not be achievable
- The lower emissions in 2030, the less the challenges
- Delayed mitigation risks
  - Escalating costs
  - High-carbon lock-in
  - Stranded assets
  - Reduced response options
  - Increasingly uneven distribution of impacts between countries

D2 Sustainable development, eradicating poverty, reducing inequalities

- The avoided climate change impacts on the above would be greater
  - if global warming is limited to 1.5°C rather than 2°C
  - if mitigation and adaptation synergies are maximized, trade-offs minimized
- Sustainable development balances social well-being, economic prosperity and environmental protection
  - Sustainable development is closely linked to climate change impacts and responses
  - United Nations Sustainable Development Goals (SDGs) provide framework for assessing these linkages
- Ethics and equity considerations help address uneven distribution of adverse impacts and responses for disadvantaged populations

D2 Sustainable development, eradicating poverty, reducing inequalities (cont.)

- Enabling conditions for mitigation and adaptation:
  - Geophysical, environmental-ecological, technological, economical, socio-cultural, institutional dimensions
  - Feasibility enhanced by multi-level governance, institutional capacity, policy instruments, technological innovation and transfer, mobilization of finance, human behaviour and lifestyle changes

D3 Adaptation: benefits and trade-offs

- Benefits
  - Synergies with sustainable development: adaptation can reduce vulnerability of human and natural systems, ensuring food and water security, health, ecosystem services, reducing disaster risks, poverty and inequality
  - Synergies with societal resilience and adaptive capacity: investing in physical and social infrastructure
  - Synergies with mitigation: land management that reduces emissions and disaster risk, or low carbon buildings also designed for efficient cooling
- Trade-offs
  - Poorly designed and implemented adaptation can increase emissions, water use and social inequality, harm health and natural ecosystems
  - Trade-off with mitigation: bioenergy crops, reforestation or afforestation competing with agricultural adaptation can undermine sustainable development
- Careful mix of adaptations and mitigation can enable rapid systemic transition if
  - Implemented in participatory and integrated way
  - Aligned with economic and sustainable development
  - Local decision makers are supported by national governments

D4 Mitigation: benefits and trade-offs

- Synergies
  - Synergies outnumber trade-offs overall
  - Net effect depends on pace, magnitude, portfolio, management of transition
  - Robust synergies exist for health, clean energy, cities and communities, responsible consumption and production, oceans
  - Most synergies, least trade-offs exist with sustainable development in pathways with:

    - Low energy demand, low material consumption, low-emissions diet
    - Lower need for carbon dioxide removal

- Trade-offs
  - Potential trade-offs exist with poverty, hunger, water, energy access
  - Poorly managed large-scale afforestation and BECCS can compete with food security, biodiversity, ecosystems
  - Risks for sustainable development exist for economies highly dependent on fossil fuels
    - Can be addressed through diversification of economy and energy sector
- Redistributive policies that shield the poor and vulnerable can resolve trade-offs
  - Represents a small fraction of total mitigation costs

D5 Enabling conditions

- System transitions enabled by financial investments, policy instruments, technological innovation, behaviour changes
- Financial investments for 1.5°C pathways
  - Around 2.4 trillion US$2010 per year (2016 to 2035) = 2.5% of global GDP
  - From private funds (institutional investors, asset managers, development or investment banks) and public funds
  - In developing countries also from development assistance, multilateral development banks, UNFCCC channels
  - Funding challenges: access to funds, mobilizing funds, the scale of finance required, limited capacity
  - Implementation challenges: energy costs, depreciation of assets, international competition
- Policy instruments that help mobilize resources
  - Government policies that lower the risk of investments
  - Shifting global investments and savings
  - Securing the equity of the transition
  - Maximizing on potential co-benefits
- Technological innovation
  - System transitions for 1.5°C pathways involve greater innovation and disruptive technologies and practices, in both industry and finance
  - Policies and international cooperation can provide incentives that promote their development, commercialization, adoption and diffusion
- Behaviour changes
  - Accelerated by education, information and community approaches

D5 Enabling conditions (cont.)

  - Informed by indigenous and local knowledge
  - More effective if combined with other policies, and tailored to motivations, capabilities, and resources of actors and contexts
- Public acceptability of policies depends on what consequences are expected, on whether these are distributed fairly, and on perceived fairness of decision making

D6 Climate-resilient development pathways

- Sustainable development can support and enable transitions to reach 1.5°C
  - Achieve development, climate adaptation and mitigation, while eradicating poverty, reducing inequalities and vulnerability, increasing resilience
  - Social justice and equity are core aspects which can reduce trade-offs, widen opportunities, protect the poor and disadvantaged
  - Development contexts and systemic vulnerabilities differ by region and by country
- 1.5°C pathways that are consistent with sustainable development
  - Have fewer mitigation and adaptation challenges, lower mitigation costs
  - Are characterised by international cooperation, equality and less poverty

D7 Strengthening the capacities for ambitious action to limit global warming to 1.5°C

- Partnerships
  - Facilitate actions and responses
  - Involve national and sub-national authorities, non-state public and private actors, institutional investors, banks, scientific institutions, private sector, civil society, indigenous peoples and local communities
- Accountable multilevel governance
  - Involves non-state actors (industry, civil society and scientific institutions)
  - Coordinated, gender sensitive, sectoral and cross-sectoral policies
  - Financing and cooperation on technology development and transfer
  - Ensures participation, transparency, capacity building and learning
- International cooperation
  - Provides an enabling environment for ambitious action in all countries and for all people, in the context of sustainable development
  - Critical enabler for developing countries and vulnerable regions

  - Enhances access to finance and technology
  - Enhances domestic capacities
- Collective efforts at all levels
  - Taking into account different circumstances and capabilities, equity, effectiveness
  - Strengthens the global response to climate change, while achieving sustainable development and eradicating poverty

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Though this document is based on the *IPCC Special Report on Global Warming of 1.5°C* Summary for Policymakers, it has not been formally endorsed by the IPCC.

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