Technical Workshop on Water and Climate Change Mitigation Inter-Dependencies

Bonn 13 June 2023

About the workshop

1. This workshop was convened to identify what is known and not known about the dependency of Paris Agreement targets on the sustainable management of water resources. This information is expected to assist Parties to the *United Nations (UN) Framework Convention on Climate Change* (UNFCCC) and the Paris agreement to incorporate water issues in their Nationally Determined Contributions (NDCs) and in UNFCCC processes, and to consider whether there should be any further assessment of these issues by the *Intergovernmental Panel on Climate Change* (IPCC).
2. The workshop was sponsored by the United Kingdom, Egypt and United Arab Emirates as the immediate past, current and next Presidencies of the *UNFCCC Conference of the Parties* (COP) respectively, and by Japan as the co-chair (with Egypt) of the *Interactive Dialogue on Water for Climate, Resilience and Environment* of the *UN 2023 Water Conference*.
3. The workshop was hosted in Bonn by the German International Cooperation Agency (GIZ) and organised by the *UN-Water Expert Group on Water and Climate Change*, comprising 35 UN organisations and other partners, co-coordinated by the UNECE, UNESCO and WMO.
4. Further information about the objectives and agenda for this workshop is at <u>Attachment 1</u>.
5. Participants are listed at <u>Attachment 2</u>.

Workshop content

6. Opening statements were given by the co-organisers and host, and key messages from the UN 2023 Water Conference and COPs were provided by the Vice-Chair of UN-Water, the co-hosts and officials of the UNFCCC and IPCC, as summarised in <u>Attachment 3</u>.
7. For technical content, the workshop considered the available information about the water requirement of the clean energy transition, the water requirements of natural systems to fulfil their carbon absorption roles, and the mitigation benefits from the improved management of water systems and water resources. A summary of discussions and presentations on the dependencies is at <u>Attachment 4</u>.
8. The workshop also heard from the secretariats to the UNFCCC and the IPCC on their relevant processes for considering these issues further and noted the intention of the co-coordinators to brief member states at a hybrid session in the Bonn Climate Conference venue the next day, hosted by the United Kingdom.
9. Participants were also invited to submit any further relevant data and other information for inclusion in the meeting documentation and to comment on the draft workshop report prior to its finalisation by the organisers.

Workshop findings

10. Based on this information, the workshop made the findings about the water dependency of climate mitigation measures at <u>Attachment 5.</u>
11. From these findings, the organisers made the following conclusions, with the 'headlines' (in bold) presented to the briefing of UN member States on the following day:

Conclusion 1: Water is a necessary part of the climate solution: without considering freshwater in mitigation and adaptation, it will be difficult to achieve the Paris Agreement

- Many key mitigation measures, necessary to achieve the 1.5 degree and 2 degree objectives of the Paris Agreement require the availability and effective management of freshwater resources. If there is not sufficient freshwater available, or the water that is available is not well enough managed to assure supply, then it will be more difficult for these measures to achieve their emission reduction objectives.
- Water dependent measures encompass the principal measures for achieving the transition to clean energy, for reducing methane and other emissions from wastewater and water treatment, distribution and other managed water resources, and for maintaining or improving the sequestration of greenhouse gases such as from afforestation and wetland restoration, including from biosphere reserves and natural heritage and coastal blue carbon ecosystems.
- The energy transition requires support with water demand reduction; water efficiency and use in homes, including energy used for hot water heating is a key interaction. A recognition that energy sufficiency is linked to water sufficiency will support energy sector decarbonisation through demand reduction and at the same time safeguard existing freshwater resources through reduced consumption.

Conclusion 2: Water availability for climate mitigation purposes cannot be assumed: Water impacts need to be considered when selecting mitigation measures, especially in water-scarce regions.

- The IPCC has assessed that ensuring water availability for some of the above purposes (particularly biofuels and afforestation) may require trade-offs with food security and possibly other objectives requiring the same water (IPCC6 SR para IPCC6 MR para). Furthermore, many mitigation measures including Carbon Dioxide Removals (CDR) approaches and technologies have considerable water footprint (high confidence) (IPCC WGII)
- In water scarce locations, where demand for freshwater already exceeds sustainable supplies, 'trade-offs' will be required for all new demands, including for climate mitigation objectives.
- Trade-offs in water are difficult as each water demand has its own social and economic priority, and the environment must itself retain enough water to provide sustainable supplies. Making freshwater through desalination is generally feasible only in coastal areas and for the highest value water uses, but itself is a high energy process and has environmental impacts. Managing water trade-offs in conditions of water scarcity requires well developed water management and water allocation policies and practices, yet many countries face water scarcity now (Water Scarcity | UN-Water) and integrated water resource management is only 54 percent implemented globally (SDG 6 Indicator 5.1). The UNFCCC parties should have a deep interest in the achievement of SDG 6 as that may be a key to unlocking progress with emission reduction goals. Also, as with all climate matters, while solutions must be found at the country level, there is an important practical role for multilateral processes in providing procedures, direction, guidance and support to ensure the common purpose is realised.

Conclusion 3: Mitigation measures can be successfully co-implemented with SDG 6 and the other water related goals of Agenda 2030.

- Through innovation in demand management, water use efficiency and infrastructure design, it should be possible to secure water for mitigation purposes without limiting other sectors.
- For example:
    - changing irrigation practices to reduce standing water can free up water for other uses while reducing emissions from these fields and while not reducing farm productivity;
    - modifying currently single purpose dams to provide for multiple services, such as clean energy (hydro-electricity), water security, irrigation and flood mitigation; and
    - improved water and land management practices at the catchment level can result in more sequestration (through soil organic carbon), improved soil and water quality for other purposes and can reduce climate impacts of fertiliser use through water *and nutrient* management.

Conclusion 4: Filling the knowledge gaps identified by the workshop through IPCC assessments and having the role of water for mitigation better represented in climate discussions are important means of securing GHG emission reductions

- GHG emission reductions will be better secured if all parties consider the freshwater implications of their proposed mitigation measures and in particular:
    - how to ensure the supply of water for these measures along with their other water-dependent priorities, such as food security, economic development, public health, biodiversity conservation and blue carbon ecosystems; and
    - scope for measures that can jointly achieve climate mitigation and water sustainability goals.
- It would support national efforts if UNFCCC parties:
    - include freshwater dependency as a specific subject area in all relevant UNFCCC work programs (such as the Global Stocktake, joint work on implementation of climate action on agriculture and food security, and work on scaling up and impacts);
    - support the preparation of principles and guidance to assist governments to identify and benefit from any possible synergies and where trade offs are required, to weigh the relative emission reduction benefit of proposed measures against the other benefits that can be gained from the available freshwater.
- The IPCC 7th cycle work program is recommended to include more detailed assessments of these dependencies, to give the latest and best estimates of the emission saving potential and water requirements, the consequences of each mitigation measure and the broader interdependence of water management, including assisting governments to work out any trade-offs required.

This report was prepared by the workshop organisers (WMO, UNESCO and UNECE) in consultation with workshop participants.

Attachment 1.

WORKSHOP CONTEXT AND AGENDA

Workshop context (as set out in the concept note)

It is well known that climate change affects global hydrology and rainfall and runoff patterns at a local scale, with unprecedented drought and flood events being experienced everywhere with increasing intensity and frequency. Even though much more needs to be done in many if not all countries to adapt to these changes in the water cycle, the linkages are generally accepted. There is no argument that climate change is affecting freshwater resources and services in many ways.

Less understood is the interaction between water and emission reductions. Water is a feedstock for renewable fuels such as hydrogen and biofuels, and is itself a source of clean energy (via hydropower) and required for cooling of nuclear power plants and the production of rare earths for battery production. Water is also required for natural ecosystems such as wetlands, peatlands and forests to provide their carbon absorption services. How water is used in irrigation, how wastewater is treated and water storage and distribution methods also directly affect emissions.

The climate mitigation targets of the Paris Agreement may be critically dependent on the availability of freshwater, yet these resources are themselves under pressure from increasing demand for food security, energy security, drinking water and sanitation and for economic development as well as being less predictable due to climate change.

There is no comprehensive information about these dependencies and the implications of this for decision-making on the emission reduction pathways and climate change and on how water is allocated and used, and no global scale accounting of this.

There may be low awareness of these interdependencies in governments and societies because while there is much analysis and reporting of the wide range of water issues and risks in detailed technical reports (particularly the *Intergovernmental Panel on Climate Change* 6th Cycle (IPCC6) Working Group III report on mitigation and IPCC6 Synthesis report, the respective *Summaries for Policy Makers* make little reference to this analysis.

Workshop agenda

- **Opening by Co-coordinators** (Introduced by facilitator Mr Nicolas Franke, WMO)
    - Elena Manaenkova, Deputy Secretary-General, WMO (online)
    - Anil Mishra, Chief of Section, Hydrological Systems and Water Scarcity Section, UNESCO
    - Sonja Koeppel, Secretary of the Water Convention, UNECE
- **Welcome by host GIZ**
  Fanni Zentai, Component Manager Water Policy – Innovation for Resilience, GIZ
- **Key message of the UN 2023 Water Conference and COPs**
    - Johannes Cullmann, UN-Water Vice Chair
    - Shinichi Kusano, Assistant Vice Minister for Risk Communication, Ministry of Land, Infrastructure, Transport and Tourism of Japan (online)
    - Andrew Roby, Senior Water Security Adviser, Foreign Commonwealth and Development Office, UK
    - Shahbano Tirmizi, Senior Advisor at COP28 Partnerships Team and Water Sector Lead, UAE (online)

    - Dr Walid Hakiki, Head of Sector, Ministry of Water Resources and Irrigation, Egypt
    - Stefan Dierks, Associate Programme Officer, Water Team, UNFCCC
- **Current state of information and analysis**
    - Abdalah Mokssit, Secretary, Intergovernmental Panel on Climate Change (IPCC)
    - Malin Lundberg Ingemarsson, Programme Manager and Team Lead Water for Resilient Landscapes, SIWI Essential Drop to Net Zero report
    - other sources (e.g. Stop Floating, Start Swimming) (open discussion led by moderator)
- **Discussion on links between water and mitigation** (led by Mr Anthony Slatyer, Consultant Water Adviser to WMO)

  Key water dependencies

  i. **for clean energy (**eg biofuels, hydrogen, hydropower) or for cooling (eg nuclear), energy storage and grid stabilisation (eg pumped hydro and rare earth production)
    - *Jinsun Lim, Energy and Environment Policy Analyst, IEA;*
    - *Richard Taylor, former Chair of the IAH Commission on Groundwater and Climate Change; (online)*
    - *Gianluca Sambucini, Sustainable Energy Division, UNECE;*
    - *Dr. Julian David Hunt, Climate and Livability Initiative, Center for Desert Agriculture, Biological and Environmental Science and Engineering Division, King Abdullah University of Science and Technology (KAUST), Saudi Arabia*

  ii. **for enabling natural ecosystems** (eg wetlands, peatlands, forests, biosphere reserves and natural heritage) to operate as carbon sinks
    - *Melissa De Kock, Senior Programme Officer, Ecosystem Division, UNEP*
    - *Jerker Tamelander, Director, Science and Policy, Secretariat of the Convention on Wetlands*
    - *Anil Mishra, Chief of Section, Hydrological Systems and Water Scarcity Section, UNESCO*

  Other key water management contributions to mitigation

  iii. **Role of cryosphere** (snow, glacier and permafrost) in mitigation
    - *Arun Bhakta Shrestha, Regional Programme Manager, River Basins & Cryosphere, ICIMOD*
    - *Prof. Dr. Julia Boike, Permafrost Research, Alfred Wegener Institute*

  iv. **irrigation systems**
    - *Maher Salman, Senior Officer/Agriculture Water Management Team Lead, Land and Water Division, FAO*
    - *Dr Giriraj Amarnath, Principal Researcher – Disaster Risk Management and Climate Resilience, International Water Management Institute (IWMI)*

  v. **wastewater**
    - *Amanda Lake, Head of Carbon and Circular Economy, Jacobs, International Water Association (IWA) Climate Smart Utilities subgroup lead*
    - *Dr Giriraj Amarnath, Principal Researcher – Disaster Risk Management and Climate Resilience, International Water Management Institute (IWMI)*

  vi. **water storage and distribution**
    - *Prof., Dr. Elpida Kolokytha, AUTh, Chair of IAHR's Working Group on the SDGs (Online)*
    - *Dr Giriraj Amarnath, Principal Researcher – Disaster Risk Management and Climate Resilience, International Water Management Institute (IWMI)*
    - **other** (open discussion led my moderator)

- **Discussion on how best to present the workshop findings**
    - Led by Lilian Daphine Lunyolo, UNFCCC and Abdalah Mokssit, Secretary, Intergovernmental Panel on Climate Change (IPCC)
- **Next steps and close**
  Led by co-coordinators:
    - Stefan Uhlenbrook, Director, Hydrology, Water Resources and Cryosphere Branch, WMO
    - Sonja Koeppel, Secretary of the Water Convention, UNECE
    - Anil Mishra, Chief of Section, Hydrological Systems and Water Scarcity Section, UNESCO

<u>Attachment 2</u>

WORKSHOP PARTICIPANTS

1. Mr. Kusano Shinichi, Assistant Vice Minister for Risk Communication, Ministry of Land, Infrastructure, Transport and Tourism of Japan
2. Mr. Tokioka Toshikazu, Director for International Coordination of River Engineering, Ministry of Land, Infrastructure, Transport and Tourism, Japan
3. Dr Walid Hakiki, Head of Sector, Ministry of Water Resources and Irrigation, Egypt
4. Mr. Andrew Roby, Senior Water Security Adviser, Foreign Commonwealth and Development Office, UK
5. Mr. Paul Deverill, Foreign Commonwealth and Development Office, UK
6. Shahbano Tirmizi, Senior Advisor at COP28 Partnerships Team and Water Sector Lead, UAE
7. Salma Zeid, Partnership s Team, COP28, UAE
8. Robbert Moree, Policy Coordinator, International Water and Climate Adaptation, Ministry of Infrastructure and Water Management, Kingdom of the Netherlands
9. Emma Voncken, International Water Affairs, Ministry of Infrastructure and Water Management, Kingdom of the Netherlands
10. Fanni Zentai, Component Manager Water Policy – Innovation for Resilience, GIZ
11. Anna Berg, Water and Climate Policy Advisor, GIZ
12. Johannes Cullmann, Vice Chair, UN-Water
13. Federico Properzi, Chief Technical Adviser, UN-Water
14. Sonja Koeppel, Secretary of the Water Convention, UNECE
15. Gianluca Sambucini, Renewable Energy, UNECE
16. Hanna Plotnykova, Water Convention, UNECE
17. Anil Mishra, Chief of Section, Hydrological Systems and Water Scarcity Section, UNESCO
18. Elena Manaenkova, Deputy Secretary-General, WMO
19. Stefan Uhlenbrook, Director, Hydrology, Water Resources and Cryosphere Branch, WMO
20. Nicolas Franke, Coordinator and Programme Officer, WMO
21. Maria Kosonen, Junior Professional Officer, WMO
22. Anthony Slatyer, Water Policy and Strategy Adviser, WMO
23. Abdalah Mokssit, Secretary, Intergovernmental Panel on Climate Change
24. Lilian Daphine Lunyolo, Coordinator, Water Team, UNFCCC
25. Stefan Dierks, Associate Programme Officer, Water Team, UNFCCC
26. Melissa De Kock, Senior Officer/Agriculture Water Management Team Lead, Ecosystem Division, UNEP
27. Maher Salman, Technical Adviser, Land and Water Division, FAO
28. Yuliya Vystavna, Isotope Hydrologist, IAEA
29. Malin Lundberg Ingemarsson, Programme Manager and Team Lead Water for Resilient Landscapes, SIWI
30. Dani Gaillard, International Process & Policy Advisor, SIWI
31. David Hebart-Coleman, Leading expert in water governance, SIWI
32. Jinsun Lim, Energy and Environment Policy Analyst, IEA;
33. Jerker Tamelander, Director, Science and Policy, Secretariat of the Convention on Wetlands
34. Ingrid Timboe, Policy Director, Alliance for Global Water Adaptation (AGWA)
35. Dr Giriraj Amarnath, Principal Researcher – Disaster Risk Management and Climate Resilience, International Water Management Institute (IWMI)
36. Dr. Julian David Hunt, Climate and Livability Initiative, Center for Desert Agriculture, Biological and Environmental Science and Engineering Division, King Abdullah University of Science and Technology (KAUST), Saudi Arabia
37. Prof. Dr. Julia Boike, Permafrost Research, Alfred Wegener Institute
38. Alex Campbell, Head of Research & Policy, International Hydropower Association
39. Prof. Dr. Elpida Kolokytha, AUTh, Chair of IAHR's Working Group on the SDGs
40. Amanda Lake, Head of Carbon and Circular Economy, Jacobs; Climate Smart Utilities subgroup lead, IWA

41. Roberto Ranzi, IAHR
42. Tom Soo, Executive Director, IAHR
43. Richard Taylor, former Chair of the IAH Commission on Groundwater and Climate Change;
44. Arun Bhakta Shrestha, Strategic Group Lead, Reducing Climate and Environmental Risks, ICIMOD

Attachment 3

SUMMARY OF OPENING STATEMENT AND KEY PROCESSES

Statements and information shared during the workshop

1. WMO Co-coordinator, Mr. Nicolas Franke, welcomed the participants on behalf of the UN-Water Expert Group on Water and Climate Change.
2. Dr. Elena Manaenkova, WMO Deputy Secretary-General opened the meeting with some remarks:
   - COP27 was the first time water was recognized in the cover decision as one of the key elements for adaptation. For WMO, water means a source of disasters and also part of national water security. Increasing number of countries have water in their NDCs. We have been working on having water in all the pillars of climate action and being recognized as part of the solution. The first Global State of Water Resources report was launched last year. We need water for biofuels, hydrogen production, cooling for nuclear power, hydropower and more. There is not enough information on water resources and their linkages to other sectors. We need to assess what IPCC knows and especially assess what IPCC doesn't know, and how countries should include water in their NDCs and NAPs.
3. UNESCO Co-coordinator, Anil Mishra, welcomed participants and mentioned the water and climate change policy brief by the UN-Water Expert Group. He highlighted 'game changer' ideas including science based assessment presented to UN 2023 Water Conference.
4. UNECE Co-coordinator, Sonja Koeppel, highlighted that climate change is water change and that water needs to be brought into the attention of negotiators and be considered in all mitigation activities. Water needs to be reflected in decisions and agreements.

Welcome by host GIZ

5. Fanni Zentai: GIZ delivered an overview of GIZ knowledge products on water and climate: Stop Floating and Start Swimming and its three key messages:
   - The mere presence of uncertainty cannot be the reason for inaction.
   - Utilize key adaptation and mitigation options in water sector.
   - Need for cross-thematic and cross-sectoral approaches.
6. Additional GIZ publications: Climate Resilient Urban Sanitation unravels the potential in sanitation: the energy chapter of Unpacking Freshwater's Role in Climate Change Mitigation, Locking Carbon in Wetlands for Enhanced Climate Action in NDCs, and Nature-Based Resilience. Upcoming: Watering the NDCs: National Climate Planning for 2020 and Beyond.

Key messages of the UN 2023 Water Conference and COPs

7. Johannes Cullmann, vice-chair of UN-Water, explained the relevant outcomes of the UN-Water conference particularly the Water Action Agenda for entities to make commitments to integrate water into their policies and national plans and focus on externalities related to water. He saw an overarching headline of 'decelerating the hydrological cycle'.
8. Shinichi Kusano, Japan, as a co-chair of the UN Water Conference Interactive Dialogue 3 explained the key messages from the dialogue as concerning the 'co-benefits' for climate and the environment of water for biodiversity, the role of resilient infrastructure, and the need for

national plans to highlight the importance of resilient water management. He gave examples from Japan for putting these objectives into practice for achieving flood mitigation through the use of hydro-power dams and urban green spaces and in government water financing.

9. Andrew Roby, UK said the Water Conference was a great success in bringing the water community together but it was lacking participation from other sectors such as energy and food and raised the need for a higher level of political attention from the largest countries.
10. Walid Hakiki, Egypt, raised the global challenge for water demand exceeding supply. After many attempts to 'water the COP', COP 27 included water in cover decision. Decoupling water consumption and economic activity is needed to reach sustainable development. Global water information systems are key to solving the water management issues. Finance mobilization remains a challenge.
11. Shahbano Tirmizi, UAE, commended the work on water that has already taken place this year and recognized it as one of the priorities. UAE is considering how to make progress on the things that have been done by the previous COP presidencies and by the water community. How to ensure that water gets the political platform that it needs? How to ensure that water is highlighted and mainstreamed across all other dialogues (such as food systems and irrigation, early warnings and disasters, health and WASH, energy, NBS, and financing etc.)? In a nutshell: water needs to be a standalone but also integrated in other dialogues across the board. We want to take on board the conclusions from the UN-Water Conference and input them into COP28. Partners can be involved through the water pavilion, promotional opportunities in the green and blue zones. UAE is working with partners to continue the conversation and elevate it.
12. Stefan Dierks highlighted UNFCCC's engagement at the UN 2023 Water Conference including the major announcements that the Executive Secretary of the UNFCCC, Mr. Simon Stiel announced. These announcements include an action pledge to deliver knowledge, catalyse innovation and advance action in addressing water-climate change challenges. Additionally, a water-climate nexus alliance will be created within the UNFCCC to convene actors from within and without the UN-system to synergistically collaborate in addressing key water-climate nexus challenges in all countries, especially least developed countries (LDCs) and Small Island Developing States (SIDS).
13. Under the agenda item on how best to present the workshop findings, Lilian Daphine Lunyolo, UNFCCC explained that the UNFCCC builds on what UN system and other actors present. For instance, the best available science by the IPCC as well as other authoritative publications by agencies and organisations. She encouraged the participants to share their work widely and track engagement opportunities to contribute to the UNFCCC process. Most emphasised was the call for submissions for views on opportunities, best practices, actionable solutions, challenges, and barriers relevant to the topics of the dialogues referred to in paragraph 13 of FCCC/PA/CMA/2022/L.17 under the Sharm el-Sheikh mitigation ambition and implementation work program work programme. She also highlighted the Global Stocktake (GST) process as a key part of engagement to look out for in the coming years. While most of the stakeholder engagement activities of the GST came to an end in June 2023, the same process will be repeated every 5 years. Lastly, she encouraged development partners to support countries in advancing their water-climate mitigation nexus priorities and ensure these are reported on adequately to be picked up easily in the national documentation such as the nationally determined contributions (NDCs) and to the extent possible the national adaptation plans (NAPs). Her remarks concluded by encouraging participants to consistently invest in rallying support towards water issues citing the example of the Ocean and Climate Change Dialogue and how it came about in the UNFCCC process.

SUMMARY OF TECHNICAL INFORMATION, DISCUSSIONS AND PRESENTATIONS

Information provided prior to the workshop on what is known about the 'water dependencies'

14. The Intergovernmental Panel on Climate Change (IPCC) has estimatedthe emission reduction potential of 32 mitigation options (summarised in IPCC6 Synthesis Report SPM figure 7). This does not set out 'dependencies' on water or any other inputs. However, around half would seem dependent on freshwater availability, either directly or indirectly, as set out below and described in square brackets (these descriptions are not in the IPCC report).

Energy supply

- Solar**** [may require water dependent dispatchable energy sources for grid stabilisation]]
- Wind*** [may require water dependent dispatchable energy sources for grid stabilisation]
- Reduce methane from coal, oil and gas*
- Bioelectricity* [requires water as feedstock]
- Geothermal [requires water for extraction and cooling] and hydropower*
- Nuclear [requires water for cooling]
- Fossil carbon capture and storage (CCS) [requires water for processing and cooling]

Land, water, food Agriculture,

- Reduce conversion of natural ecosystems**** [requires water for ecosystem functioning]
- Carbon sequestration in agriculture*** [requires water to enable carbon absorption in soils]
- Ecosystem restoration, afforestation, reforestation** [requires water for ecosystem functioning]
- Shift to sustainable healthy diets [requires access to safe drinking water]
- Improved sustainable forest management* [requires water for ecosystem functioning]
- Reduce methane CH4 and N2 in agriculture [includes emissions from irrigation]
- Reduce food loss and waste

Settlements and infrastructure

- Efficient buildings
- Fuel efficient vehicles
- Electric vehicles [requires water for producing rare earths for batteries]
- Efficient lighting, appliances and equipment
- Public transport and bicycling
- Biofuels for transport [requires water for growth of biofuel crops]
- Efficient shipping and aviation
- Avoid demand for energy services [water sector a major energy user]
- Onsite renewables

Industry and waste

- Fuel switching[1] [requires water for growth of biofuel crops and as feedstock for hydrogen]
- Reduce emission of fluorinated gas
- Energy efficiency
- Material efficiency
- Reduce methane from CH4 emissions from waste / wastewater

[1] = degree of significance, with a contribution to net emission reduction of at least one gigatonne of CO2 equivalent per year per asterisk shown: eg solar has mitigation potential of at least 4 gigatonnes per year.

- Construction materials substitution
- Enhanced recycling
- Carbon capture with utilisation (CCU) and CCS

15. The IPCC's assessments include many references to water-related risks to mitigation measures without making any definite conclusions. An example of IPCC commentary is:

    "The viable speed and scope of a low-carbon energy system transition will depend on how well it can support SDGs and other societal objectives (high confidence). Energy systems are linked to a range of societal objectives, including energy access, air and water pollution, health, energy security, water security, food security, economic prosperity, international competitiveness, and employment. These linkages and their importance vary among regions." (IPCC6 MR Technical Summary).

16. The IPCC6 Mitigation Report and Land Report have many specific references to water availability risks. However, these are not reflected in the Synthesis Report and Summary for Policy Makers except in regard to bio-energy and afforestation, pointing to risks while also saying mitigation measures generally align with the SDGs:
17. "Mitigation options often have synergies with other aspects of sustainable development, but some options can also have trade-offs. There are potential synergies between sustainable development and, for instance, energy efficiency and renewable energy. Similarly, depending on the context, biological CDR methods like reforestation, improved forest management, soil carbon sequestration, peatland restoration and coastal blue carbon management can enhance biodiversity and ecosystem functions, employment and local livelihoods. However, afforestation or production of biomass crops can have adverse socio-economic and environmental impacts, including on biodiversity, food and water security, local livelihoods and the rights of Indigenous Peoples, especially if implemented at large scales and where land tenure is insecure". (IPCC6 SR SPM B.6.4)
18. The IPCC6 Land Report includes more specific reference to water in its discussion on afforestation and biomass cropping, pointing to risks while also saying for mitigation measures

    "While it is therefore currently not possible to project the area at risk of degradation … there is a clear risk that expansion of energy crops at the scale anticipated could put significant strain on land systems, biosphere integrity, freshwater supply and biogeochemical flows" IPCC SRCCL 1.5.2)

19. The IPCC6 Synthesis report acknowledges the need for 'trade-offs' with water access and the need for frameworks for integrated policy implementation:

    "… Trade-offs in terms of employment, water use, land-use competition and biodiversity, as well as access to, and the affordability of, energy, food, and water can be avoided by well-implemented land-based mitigation options, especially those that do not threaten existing sustainable land uses and land rights, with frameworks for integrated policy implementation (high confidence)" (IPPC6 SR4.9).

20. This understates the 'real-world' risk as few countries have 'frameworks for integrated policy implementation' as would allow these risks to be managed.
21. The International Energy Agency (IEA) outlooks and analysis and the International Renewable Energy Agency (IRENA) and International Hydropower Association (IHA) Outlook reports provide

a wealth of data and analysis from an energy sector perspective. This includes modelling of expected future energy demand and the growth trajectory and composition of clean energy sources under a net zero scenario. Their estimates of growth of energy production from different energy types is a necessary but not sufficient input to working out the water requirements of the Paris Agreement mitigation objective.

22. The Global Water Intelligence report estimates scope 1 and scope 2 emissions from water services, wastewater and sanitation services sector of 847MCO2e-100.
23. The GIZ report Stop Floating, Start Swimming chapter on mitigation reviews and discusses the capacity to reduce emissions from water and wastewater services, surface waters, peatlands and rice. The report advises, "*GHG emissions from these … categories might cause more than 10% of global anthropogenic GHG emissions, rendering water security a potentially vital element of global climate mitigation activities and strategies*." This is the only report reviewed for this workshop which ventures a number giving materiality to the water dependency – though this 10% is very likely to be only a fraction of the total water dependency.
24. The Stockholm International Water Institute report Essential Drop to Net Zero, still in preparation, will be the most comprehensive water focussed assessment of all the opportunities. It discusses the water contribution to the mitigation of emissions from drinking water and sanitation services (published), energy systems (hydropower, bioenergy, geothermal, nuclear, solar and wind) (published), freshwater systems (in preparation) and land systems (in preparation).

Information provided prior to the workshop on what was thought to be <u>not known</u> about the 'water dependencies'

25. The information now available does not inform climate policymakers of the consequences for the emission reduction targets of mitigation measures not being achieved due to water constraints. This denies them insight of critical risks to their agreed objectives and may explain why these issues have not been prioritised by them for further work in the UNFCCC subsidiary bodies and the IPCC.
26. The information now available at a global scale also does not inform water policymakers of:
    a. expected water required (in volumetric terms) to implement each measure at the scale required to achieve the Paris Agreement targets;
    b. effects of this demand on other water-dependent objectives such as food security; and
    c. examples of water policies and practices able to resolve any required trade-offs.
27. In the absence of any authorisation under the COP or other inter-government processes, there are also no globally applicable principles and guidance on how to weigh the relative emission reduction benefit against the food security, environmental and other benefits that can be gained from each available unit of freshwater supply.

Workshop discussion on the current state of information and analysis

28. Abdallay Mokssit, Secretary of IPCC, explained key elements of the IPCC 6th cycle outcomes and processes for the 7th cycle work program. Climate change is already a threat to human wellbeing and health of the planet. Only with immediate and serious emissions reductions can 1.5 degrees be not breached. Water insecurity mostly impacts poor, women and marginalized populations and can contribute to social unrest. The warming climate increases drought and

flood risk, makes rainfall and river discharge more variable. Decreased river flows from 1970-2010 have had negative and cascading impacts on multiple sectors including hydropower generation. Land and its associated freshwater resources are also under growing human pressure and is a critical resource for food, water, health and wellbeing. Bioenergy increases the competition over land. Co-benefits for mitigation include diversification of farming systems, use of cover crops, and biochar. Reducing deforestation and forest degradation lowers GHG emissions and can also contribute to adaptation goals. Water harvesting and micro-irrigation, agroforestry and other agroecologically focused farming methods can be used.

29. Malin Lundberg Ingemarsson, SIWI, introduced the work on Essential Drop to Net Zero report. Assessed links between land systems, freshwater ecosystems and technological systems and accounting for green water, blue water and water quality. WASH chapter divides emissions to direct and indirect emissions. Wastewater emissions produce 1-3% of the GHG emissions as direct and 4% of indirect emissions. Mitigation actions to reduce GHG emissions include wetlands, rivers and lakes and reservoirs and require a basin scale approach.
30. Water will be crucial for expanding clean energy production from the land. With BECCS future water demand will exceed the supply. There is not enough water to use a siloed approach. More data is needed. Unmanaged water risks can limit success of mitigation measures. There are win-wins for water and climate security. Key messages are: 1) Climate mitigation depends on freshwater and impacts freshwater. 2) promote win-wins for water wise climate transitions 3) ecosystems ability to store GHG in fundamentally dependent on the water cycle 4) demand on water will exceed availability.
31. David Hebart-Coleman, SIWI, notes from the enhanced NDCs water and wastewater is not seen as important standalone (wastewater in 32%). Ecosystems in NDCs approx. in 42%. Freshwater ecosystems and NDCs: wetlands were in 49% of NDCs. Only 16% of NDCs linked energy and water. Water is treated as an input but not how energy is affecting water. Agriculture 36% included water however 32% had no inclusion of water. Very few water-related (measurable) targets in either mitigation or adaptation. Lack of integration and coordination on water.

Workshop discussion on water dependencies for each mitigation type

Clean energy

32. Jinsun Lim, IEA, addressed the energy-water nexus. Water is used in cooling thermal power plants, mining, and hydropower generation. On the other hand, energy is used for water supply (e.g. water pumping). Currently, around 10% of global freshwater withdrawals are used for energy. Global freshwater withdrawals might increase initially but decline in the long-term with green energy due to reduced thermal cooling consumption and improved energy efficiency. However, the potential deployment of some low-emission technologies with higher water requirements, such as biofuels, concentrated solar power, carbon capture and nuclear, water use in the energy sector may increase (e.g., cooling water demand for nuclear power plants is generally higher than for fossil-fuelled thermal power plants per megawatt hour). Therefore, it is difficult to assess the water needs in the future with clean energy transitions.
33. Hydropower is one of the backbones for green energy transition, and is expected to double by 2050 in the IEA's Net Zero Emissions by 2050 scenario. The IEA's Climate Impacts on Hydropower series (based on different climate scenarios and global hydrological models) show that some regions will experience increases while others seeing decreases. For instance, Latin America

hydropower capacity factors are projected to decrease 7-17% depending on different climate scenarios. In addition to the geographical variability, different hydropower technologies have different levels of adaptability to climate change.

34. Critical minerals, which are essential for key clean energy technologies (solar, batteries etc.) also require water. 50% of lithium production sites, which generally uses more water than other minerals mining, are in highly water scarce areas. Hydrogen, another new key clean energy source, also requires water, consuming 1.5 billion cubic meters and is estimated to consume 3 billion by 2050. Efficiency may increase because it’s an emerging technology but could benefit from the hydrological experts inputs for estimation.
35. Gianluca Sambucini, UNECE: share of countries renewable energy was 18.2%, and EU countries have planned to increase the share to 40% by 2030. We strive to support countries in integrating their water and energy planning. 80% of the energy today comes from thermonuclear energy, 15% of existing nuclear power plants are in water stressed areas. 30% of plants are in high water risk areas. Water and climate mitigation can only happen together.
36. Julian David Hunt, KAUST: After the war in Ukraine and increased natural gas prices, pumped hydro storage (PHS) has again become the cheapest alternative for flexible power in Europe and many other regions. PHS provides mainly daily and weekly energy storage services. PHS offers valuable water management solutions and plays a significant role in fully decarbonizing the economy and adapting to climate change. The steep increase in variable renewable energy sources also increases the demand for daily, weekly, monthly, seasonal and pluriannual energy storage. The only options for seasonal and pluriannual renewable energy storage today are hydropower, seasonal pumped hydro storage and hydrogen. Currently, there are only around 20 seasonal pumped hydro storage plants in Austria, Switzerland, France, Italy, Norway and the USA. Given its high dam altitudes (150-300m) and reservoir level variation (100-150 m), seasonal pumped hydro storage (SPHS) plants store large volumes of water and cold (from winter to summer) with a low land requirement, low environmental impact, low evaporation, no sedimentation and no disruption of a river stream. In locations with energy and water conflicts, seasonal pumped hydro storage could be built upstream of existing hydropower dams and store electricity during the summer and generate electricity during the winter. The existing dam would then store the water released from the SPHS during the winter and release it during the summer. This would fulfill the energy needs of upstream countries and the water needs of downstream countries. This arrangement can be used in many other regions with energy and water conflicts. In desert locations, SPHS could store desalinated water and, thus, allow more water to be desalinated during the winter when electricity demand is low. It is estimated that storing 10% of the global superficial water available can store the energy equivalent to the current global electricity demand. Due to the pressure of the water column in hydropower reservoirs and lakes, hydrogen tanks made of cheap high-density polyethylene filled with ballast (sand) can be placed on the bottom of these reservoirs and lakes, providing a cheap alternative to hydrogen storage. This is because the pressure inside the tank will be the same as outside pressure. When hydrogen is extracted from the tank, its volume is replaced by water. This is possible because hydrogen is highly insoluble in water. The global potential for hydrogen storage in reservoirs and lakes is 15 PWh.
37. Alex Campbell, IHA: 15% of the world’s energy is produced by hydropower and this is a critical part of the clean energy system due to its flexibility. At 4400TWH to 8000TWH hydropower will still be the third largest energy source in the future. Important to differentiate between

consumptive and non-consumptive use of water. For example, when water it is in a reservoir and then used for energy generation it is available for other uses afterwards.

38. Arun Bhakta Shrestha, ICIMOD, Hydropower has the potential to contribute to carbon emission reduction by replacing fossil fuel-based energy sources. In fact, hydropower has the capacity to prevent approximately 3 gigatons of CO_2 emissions per year, which accounts for about 9% of the global annual CO_2 reduction. However, it's important to note that hydropower reservoirs themselves can be significant sources of greenhouse gas (GHG) emissions. These reservoirs collectively emit approximately one billion tonnes of GHGs annually, representing about 1.3% of the total annual anthropogenic emissions. Despite the GHG emissions associated with hydropower reservoirs, the overall net benefit of hydropower remains positive. However, it is crucial to address the environmental concerns associated with hydropower development and strive for sustainable hydropower. There is a significant knowledge gap regarding the interconnections between permafrost and GHG dynamics in the Hindukush Himalaya region, necessitating further research in this area.

Natural ecosystems

39. Melissa De Kock: Freshwater ecosystems explorer requires more wetlands data. However only 5-8% of land surface hold 20-30% of natural carbon. Important for regulating, capturing and storing GHG. Closing data gaps on water ecosystems through publications such as "Measuring Progress towards achieving the environmental dimension of the SDGs".
40. Jerker Tamelander, Secretariat of the Convention on Wetlands: Wetlands are a critical element of the hydrological cycle and of earth's climate system, but not addressed in detail in IPCC AR6. Half of 50 million hectares of currently drained wetlands need to be rewetted in order to reach 1.5 target. Restoration and avoiding degradation are both hugely important. Rewetting peatlands may lead to a short term spike in methane emissions, but the longer-term climate benefits of restoration are much higher than maintaining the drained status quo. At the end of 2022 only 13% of countries with peatlands have included them in their NDCs. Data is a limiting factor, wetland inventory has to be strengthened and also needs to entail making better use of existing institutions. For data to feed into decision making it needs to be part of institutional systems that cross sectors, this is currently lacking or not strong enough. Ecosystems need water but also provide water which makes their water dependency more complex to assess. How will this gap be considered in the IPCC 7th cycle work program? We need to be mindful and honest about the opportunity costs of different policies on climate scenarios (win-win-lose situations).
41. Anil Mishra UNESCO: Water plays an important role in all Climate Action: Mitigation, Adaptation and Migration. Climate change is experienced first and foremost through changes in water regimes. For Water Secure World in a changing environment science needs to be in action. Mitigation measures and CDRs have trade-offs with water and food security. Many mitigation measures (including CDR approaches and technologies) have considerable water footprint (IPCC high confidence). Forests of UNESCO world heritage sites sequester 190 million tonnes of CO_2 annually.

Cryosphere

42. Arun Bhakta Shrestha, ICIMOD, highlighted melt water relevance for reservoirs and energy, Loss of cryosphere is crossing the threshold level, Himalayan glaciers are expected to lose 20-50% of their mass. Our understanding of permafrost in the Himalayan region is limited compared to other areas. For example, the Antarctic region has an extensive coverage of permafrost,

spanning 9 million square kilometers, containing approximately 60 billion tons of CH_4 (methane) and 560 billion tons of organic carbon. In contrast, the Hindu Kush Himalaya region has around 1.2 million square meters of permafrost, but the quantity of carbon stored within it is still unknown.

43. Julia Boike, Alfred Wegener Institute; provided data on the loss of ice stored in permafrost, sea ice, glacier and ice caps. She further highlighted the need to better understand the consequences of the melted water, where it is going, and how it links to mitigation efforts

Irrigation systems

44. Maher Salman, Irrigated croplands increased 70%, 115% increase in water withdrawals, between 1972-2022. Improving water use efficiency can improve soil carbon capture and energy consumption.
45. Giriraj Amarnath, solar-led food system transformation trajectories, 97% off-grid solar for use in agriculture has been deployed in India and Bangladesh.

Water services

46. Amanda Lake, IWA / Jacobs: water sector is significant contributor to GHG emissions as well as key to mitigation. Water efficiency in homes supports demand reduction in energy. However, there is a lack of evidence; in particular for mitigation benefits of water efficiency and process emissions of nitrous oxide and methane produced during wastewater treatment (WWT). Globally, methane from WWT is estimated 7-12% of global methane emissions. Nitrous oxide emissions from WWT may be 3-4% of total global N_2O emissions. Water use in homes, 5.5% emissions. Emissions are likely under-estimated with high uncertainty relative to other sector emissions. When measured these will increase Global Stocktake figures.
47. Wastewater contains an estimated greater than four times as much energy than is current expended treating it – and hence has unrealised potential as a renewable energy and circular materials source supporting wider mitigation. Wider sectoral climate impacts are not well understood (e.g. recovered fertilisers which in addition to alleviating water quality pressures, may be recycled to agriculture or industry, reducing reliance on fossil-based fertilisers). Reuse of water supports the water required for mitigation and adaptation as well as resilience of ecosystems.
48. GHG emissions reductions will be better secured if all parties consider the implications of urban water management and in particular wastewater use, reuse and resource recovery – including its role in providing freshwater environmental flows, its impacts and potential for nutrient management and residuals management which can both impact freshwater quality (through pollution and runoff) and effect mitigation (e.g. resource recovery including biogas, fertilisers).

Water storage and distribution

49. Elpida Kolokytha, IAHR, explained risks of sedimentation of reservoirs which is both an emission source and constrains hydropower potential. Sediment accumulation in dams is a “known hotspot” for GHG emissions. Sedimentation-driven methane emissions from dammed river hotspot sites can potentially increase global freshwater emissions by up to 7%. There are millions of small dams worldwide that receive and trap high loads of organic carbon and can therefore potentially emit significant amounts of methane to the atmosphere. It is worth mentioning that although there is a significant contribution of water storage and distribution systems to mitigation, we are lacking comprehensive global data about the impact and also about where the best solutions are.

WORKSHOP FINDINGS

The workshop considered the available information on the water dependency of the items listed on the workshop agenda showed that reducing greenhouse gas emissions and achieving sequestration is dependent in varying degrees on the availability and effective management of freshwater, as summarised in the three Annexes:

- Annex 1 water dependencies of climate mitigation through clean energy.
- Annex 2 water dependencies of climate mitigation through enabling natural ecosystems.
- Annex 3 water dependencies of climate mitigation through other measures (irrigation, water services etc).

The tables have been prepared to show in an accessible format how the dependencies have been considered by the workshop. The tables have no status as a reference document, and the information in them should not be read as having been independently reviewed or verified by the workshop.

Notes to the Annex:

Note 1: Classified in accordance with the workshop agenda. Emission reduction estimates interpolated from IPCC Figure SPM.7) table

Note 2: References in the tables and their links are:

Intergovernmental Panel on Climate Change (IPCC reports)

- TP =Technical Paper on Climate Change and Water (2008)
- CCL = IPCC6 Special Report on Climate Change and Land (2019)
- MR = IPCC6 WG3 Mitigation Report (2022)
- SR = IPCC6 Synthesis Report (2023)

International Energy Agency (IEA) reports

- IEA World Energy Outlook (annual reports)
- IEA Climate Resilience for Energy Security (2022)
- IEA Electricity Security – Climate Resilience (2021)
- IEA Climate Impacts on South and Southeast Asian Hydropower (2021)
- IEA Climate Impacts on Latin American Hydropower (2021)
- IEA Climate Impacts on African Hydropower (2020)
- IEA Clean energy can help to ease the water crisis (2023)
- IEA Climate Resilience for Energy Transitions in the Middle East and North Africa (forthcoming)
- IEA all = all fuels and technologies (current)
- IEA hydrogen = hydrogen (current)
- IEA renewables = renewables (current)
- IEA solar = solar (current)
- IEA wind = wind (current)
- IEA DAC = direct air capture (current)

Other reports

- GIZ = Stop Floating, Start Swimming
- GWI = Global Water Intelligence Water Without Carbon
- IRENA = International Renewable Energy Agency: World Energy Transitions Outlook 2023
- IHA = International Hydropower Association: 2023 World Hydropower Outlook
- SIWI = Essential Drop to Net Zero

Many more primary references are referenced in these publications.

Note 3: GtCe/ yr -means gigatonnes of CO2 equivalent emissions abated per year

Note 4: GL/year = gigalitres of water required per year to achieve the stated emission reduction benefit.

Note 5: These messages the workshop's interpretation and are not quotes from the references.

Layout of all Annexes

- Column 1: The mitigation type identified in the references, and mitigation potential of each (see below):
- Column 2: The specific references to water dependency
- Column 3: A brief explanation of how the mitigation water' would be used, and any global data volume of water required to achieve this (not well populated due to lack of data at the global scale)
- Column 4: Any other key messages arising from the references.
- Column 5: A description of the potential water consequences and issues that would require active management to implement the measure.

<u>Column 1 mitigation potential background:</u>

Key references for the scale of total emissions and mitigation requirements (from IPP6 SPM):

SPM A.1.4 Global net anthropogenic GHG emissions have been estimated to be 59±6.6 GtCO2-eq9 in 2019, about 12% (6.5 GtCO2-eq) higher than in 2010 and 54% (21 GtCO2-eq) higher than in 1990, with the largest share and growth in gross GHG emissions occurring in CO2 from fossil fuels combustion and industrial processes (CO2-FFI) followed by methane, whereas the highest relative growth occurred in fluorinated gases (F-gases), starting from low levels in 1990. Average annual GHG emissions during 2010-2019 were higher than in any previous decade on record, while the rate of growth between 2010 and 2019 (1.3% year-1) was lower than that between 2000 and 2009 (2.1% year-1). In 2019, approximately 79% of global GHG emissions came from the sectors of energy, industry, transport and buildings together and 22%10 from agriculture, forestry and other land use (AFOLU). Emissions reductions in CO2-FFI due to improvements in energy intensity of GDP and carbon intensity of energy, have been less than emissions increases from rising global activity levels in industry, energy supply, transport, agriculture and buildings. (high confidence) {2.1.1}

A.2.3 Climate change has caused substantial damages, and increasingly irreversible losses, in terrestrial, freshwater, cryospheric, and coastal and open ocean ecosystems (high confidence). Hundreds of local losses of species have been driven by increases in the magnitude of heat extremes (high confidence) with mass mortality events recorded on land and in the ocean (very high confidence). Impacts on some ecosystems are approaching irreversibility such as the impacts of hydrological changes resulting from the retreat of glaciers, or the changes in some mountain (medium confidence) and Arctic ecosystems driven by permafrost thaw (high confidence). {2.1.2, Figure 2.3} (Figure SPM.1)

B.5.2 For every 1000 GtCO$_2$ emitted by human activity, global surface temperature rises by 0.45°C (best estimate, with a likely range from 0.27 to 0.63°C). The best estimates of the remaining carbon budgets from the beginning of 2020 are 500 GtCO$_2$ for a 50% likelihood of limiting global warming to 1.5°C and 1150 GtCO$_2$ for a 67% likelihood of limiting warming to 2°C[40]. The stronger the reductions in non-CO$_2$ emissions the lower the resulting temperatures are for a given remaining carbon budget or the larger remaining carbon budget for the same level of temperature change. {3.3.1}

WATER DEPENDENCIES OF CLIMATE MITIGATION THROUGH CLEAN ENERGY

Mitigation type and mitigation potential [1]	**References**[2]	**Water required for… Water volume needed**[4]	**Other key messages from references**[5]	**Potential water consequences / issues that would require active management**[6]
Bioenergy =~1.7 GtCe/yr incl BECCS + 0.8 GtCe/yr) for biofuels)	IPPC6 WG3 • SPM C11.2 • SPM D2.3 • 1.4.3 • 1.4.8 • 12.5.3 • 17.3.3.2 IPCC SRTCC • 1.5.2 IEA Renewables SIWI	Growth of biomass Water required = ? GL/yr	Increased water demand for this use may require trade-offs with other objectives eg food security.	Increased freshwater demand for this use would require trade-offs with other objectives eg food security.
Hydrogen	IPCC6 WG3 • 3.7.2.2 • 4.4.2.2 • FAQ4.3 • 6ES • 6.4.2.6 • 6.6.2.4 IEA Hydrogen	Chemical conversion. Thermal cooling Water required = ? GL/yr	Water availability needs to be taken into account for hydrogen deployment. To understand it better further research is required.	Increased freshwater demand for this use would require trade-offs with other objectives eg food security.
Hydropower = ~1 GtCe/yr incl. from geothermal)	IPCC6 WG3 • 3.7.4.1 • 6.1 • 6.2 • 6.4.2.3 • 12.5.3	Power generation Water required = ? GL/yr	Doubling of hydropower from 2022's 1,394 GW likely required for 2050 (IEA/ IRENA) . Hydropower affects flow regimes for downstream water users and may	Well planned and managed hydropower facilities can serve multiple purposes, including flood and drought mitigation and control. However water stored for increased hydropower affects flows patterns for downstream water users and requires

	• 17.3.3.2 IEA Climate Impacts on Hydropower series, IEA Renewables IHA 2023 Outlook SIWI Hydropower Special Market Report (IEA) [https://www.iea.org/reports/hydropower-special-market-report] The changing role of hydropower: Challenges and opportunities (IRENA) [https://www.irena.org/Publications/2023/Feb/The-changing-role-of-hydropower-Challenges-and-opportunities] World Energy Transitions Outlook (IRENA) [this along side the IEA net zero set out the scale of hydropower needed for net zero]		have trade-offs with other objectives eg flood mitigation. (IPCC)	trade-offs with other objectives eg flood mitigation. Evaporation losses from reservoirs also reduces water available for downstream users.
Solar (= ~4.5 GtCe/yr) Wind (= ~3.94 GtCe/yr)	IEA Wind IEA Solar SIWI	Pumped hydro for dispatchable energy supply at grid scale Water required	Except from concentrated solar power plants, water requirements for solar PV and wind power	Rapid penetration of wind and solar PV that are known to be less dependent on water than thermal plants could decrease global water withdrawals (IEA)

		= ? GL/yr	plants are comparably low (IWA)	These sources may require water dependent dispatchable energy sources for grid stabilisation. Evaporation losses from additional reservoirs and effects on flow patterns may reduce water available for downstream users. (KAUST)
Batteries = ~0.8 GtCe/yr for electric vehicles	IPCC6 WG3 12.6.1.1 IEA all	Rare earth mining operations. Water required = ? GL/yr	Water dependency not discussed or estimated. Production of critical minerals (eg lithium) for batteries requires significant quantities of water (IWA)	Increasing freshwater demand for this purpose would require trade-offs with other objectives eg food security. In coastal location, seawater may be used for some services.
Clean thermo-electric power (such as nuclear, biomass, geothermal) = ~0.9 GtCe/y for nuclear	IPCC6 WG3 • 6.4.2.4 • 6.4.2.9 • 12.5.3 • 17.3.3.2 IEA all SIWI (nuclear and geothermal)	Cooling Water required = ? GL/yr	Reduced dependence on high emission thermal power may reduce water requirements, and release water for other purposes.	Increased freshwater demand for this use would require trade-offs with other objectives eg food security. Note reduced dependence on thermal power may reduce water availability risks, and release water for other purposes.

WATER DEPENDENCIES OF CLIMATE MITIGATION THROUGH ENABLING NATURAL ECOSYSTEMS

Mitigation type and mitigation potential [1 3]	**References**[2]	**Water required for… Mitigation potential**[3] **Water volume needed**[4]	**Other key messages from references**[5]	**Potential water consequences / issues that would require active management**[6]
Maintenance of the hydrology of wetlands, peatlands permafrost and other natural systems = ~4 GtCe/yr) = 0.5-2.1 GtCe/y (peatlands and coastal wetlands restoration only (IPCCMR TS 7r	IPCC6 AR6 • 4.5.4 • 4.9 IPPC6 WG3 • SPM C9.2 • SPM C11.2 • SPM D2.5 • TS Table 7 • 7.4.2.6 • 7.6.5 • Table 12.10 IPCC3 SRCCL • 1.6.1 GIZ (peatlands)	Maintaining natural functions Water required = ? GL/yr	Wetland hold 20-30% of global organic soil carbon. (WEP) Permafrost thawing a major source of CH4 release. Lowering water tables of peatlands causes CO2 and N2O release.	Maintaining or restoring the natural hydrology of these ecosystems would have many environment co-benefits and would reduce the current social and economic services they provide.
Tree planting ('afforestation') = ~2.9 GtCe/yr) = 0.5-10 GtCe/yr (IPCC MR TS.7) 1.7 and –2.4 GtCe/yr (SRCCL 2.6.2)	IPCC AR6 • 4.5.4 • 4.9 IPCC6 MR • SPM C9.2 • SPM C11.2 • SPM D2.3 • TS Table 7 • 4.4.2.2 • 7.4.2.2 • Table 12.10	Maintaining natural functions Water required?	Increased water demand for this use may require trade-offs with other objectives eg food security. Forests absorb 40% 15.2 billion tonnes of CO2) of global emissions. (UNEP) SDG6.6 indicator shows rapid pace of wetlands loss. (UNEP)	Increased forest planting adding to freshwater absorption would have many environment co-benefits and by reducing inflows to rivers, and supply to downstream water users, may require trade-offs with other objectives.

	• 17.3.3.2 IPCC3 SRCCL • 2.6.2			
Carbon sequestration via carbon capture and storage (BECCS): = 0.5-11 GtCe/ yr (IPCC MR TS.7) = 6.5, –11 and –14.9 GtCe/yr (SRCCL 2.6.2)= 1.7 GtCe/yr incl BECCS	IPCC6 MR • 4.2.5.3 • 4.2.5.13 • 6.7.7.7 • 7.6.4.3 • Table 12.10 • Table TS.7 IPCC3 SRCCL	Maximising sequestration potential Water required	Water dependency not discussed	Increased soil carbon adding to freshwater absorption would have many environment co-benefits and by reducing inflows to rivers, and supply to downstream water users, may require trade-offs with other objectives.

WATER DEPENDENCIES OF CLIMATE MITIGATION THROUGH OTHER MEASURES (IRRIGATION WATER SERVICES ETC)

Mitigation type and mitigation potential [1 3]	**References**[2]	**Water required for… Water volume needed (if applicable)**	**Other key messages from references**[5]	**Potential water consequences / issues that would require active management**[6]
Irrigation water management =0.3GtCe/ year	IPCC3 WG3 • 7.4.3.5 • 17.3.3.2 IPCC3 SRCCL • 2.6.1.1 GIZ (rice)	N/A	Saves water for other uses.	Would save water for other uses and may affect farm productivity.
Wastewater management = 3% global CO2E	GIZ	N/A		
Managed waterways and other wetlands	IPCC3 SRCCL • 1.6.1 GIZ	Restore natural functioning (eg natural rise and fall of rivers and lakes). Water required = ? GL/yr	Rewetting can increase emissions.	May affect navigation and recreation uses depending on constant water levels, and cause adjacent property assets to be more vulnerable to flooding.
Water storages	IPCC3 SRCCL GIZ https://pubs.acs.org/doi/abs/10.1021/es4003907	Filling reservoirs in a low emission manner. Water required = ? GL/yr	Discussed in GIZ. Sediment accumulation in storages could contribute up to 7% of freshwater emissions (IAHR). .	Removing vegetation would add to construction costs. Opportunities for floating solar to reducer evaporation losses (UNECE) Need to design and operate storages and manage upstream catchment to reduce sediment inflow.
Direct Air Carbon Capture and Storage Mitigation potential = 100-300 GtCe/ yr	IPCC 6 MR • Table TS.7 • IEA DAC	Solvent regeneration Water required = ? GL per annum	1-7 tonnes water evaporated per tonne CO2	Trade-off with other water demands