



POLICY BRIEF

MELTING GLACIERS,  
THREATENED LIVELIHOODS:

# CONFRONTING CLIMATE CHANGE TO SAVE THE THIRD POLE

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## ABSTRACT

The region of Asia containing contiguous ranges of high glaciated mountains is often referred to as the Third Pole. According to *The Hindu Kush Himalaya Assessment* (Wester et al., 2019)<sup>1</sup>, even with the increase in global average temperature capped at 1.5°C above pre-industrial levels, glaciers in the region will lose one third of their ice volume by the year 2100. If current emission trends were to continue, the mountains would lose two thirds of their ice volume by 2100. The region contains the world's third largest storage of frozen water. Glaciers here provide a key source of dry-season water in the ten major river systems; loss of this water source affects agriculture, drinking water, and hydroelectricity production. Over 240 million people live in the Himalaya and nearby mountains; 1.7 billion live in the river basins downstream, while food grown in these river basins reaches 3 billion. Major efforts will be needed to adapt to the coming changes.

The melting of the Third Pole does not take place in isolation. It is closely connected to the same human activities and drivers that are also polluting the region's air, driving global climate change and raising sea levels. The countries surrounding High Mountain Asia have some of the worst air pollution in the world, and are very sensitive to changes in monsoon precipitation. Addressing all of these issues together requires ambitious and coordinated mitigation actions. The world's economy has no choice but an urgent move to net zero emissions of greenhouse gases; it must shift away from fossil fuel use in energy, transport, and other sectors, while changing diets and agricultural practices. The countries of the region also need to reduce emissions of black carbon and other short-lived air pollutants that have a climate impact and are contributing to melting the Third Pole. Luckily, addressing many of the same combustion sources provides climate, air quality and health co-benefits. Everyone has a role to play in the major changes needed in the coming decade, from individuals to governments to UNDP. This brief distills the latest science on an ominous possible future and suggests urgent responses.

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<sup>1</sup> Arnico Panday was a coordinating lead author of this assessment.

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## INTRODUCTION

**Earth's third largest storage of frozen water after Antarctica and the Arctic<sup>2</sup> lies in the high mountains of Asia.** This has prompted the region's nickname: the Third Pole.<sup>3</sup> Centred on the Tibetan Plateau, this region contains every peak on Earth taller than 7,000 meters. The Himalayan arc flanks the region's south, starting from northern Myanmar, spanning the southern edge of the Tibetan Plateau, the northern edge of northeast India, across Bhutan, Sikkim, Nepal, and the western Himalayan states of India. Separated from the Western Himalaya by the arid Ladakh Valley, the Karakoram range extends north-westwards, connecting to the Hindu Kush Mountains on the Afghanistan-Pakistan border. Together these ranges form the Hindu Kush Karakoram Himalaya (HKH). The Hengduan and Quilian Mountains sit at the eastern side of the Tibetan Plateau, with the Kunlun on the northwest and north. The Pamir Mountains extend north from the Hindu Kush, shared by Afghanistan, China, Kyrgyzstan, and Tajikistan. Further north are the Tien Shan Mountains, shared by China, Kazakhstan, and Kyrgyzstan, and extending eastwards around the northern edge of the arid Tarim Basin. Figure 1 shows a map of High Mountain Asia and its sub-regions.

**High Mountain Asia's frozen water, its cryosphere, is stored in several different forms, including in snowfields, glaciers, permafrost, and seasonal ice on lakes and rivers.** In 2015, glaciers covered almost 100,000 square kilometres (km)<sup>5</sup> of High Mountain Asia, containing 3,000-4,700 cubic km of ice (Bolch et al., 2019), with just under half in the Himalaya and Karakoram (Nie et al., 2021). During winters, large parts of High Mountain Asia experience snowfall, while many lakes and high altitude stretches of rivers freeze. When glaciers retreat, vacated depressions often fill with water, forming glacial lakes. The exact number of glacial lakes is not firmly established, and varies in time; estimates range from 4,260 to 8,200 for the HKH region, including 1,466 to 2,323 lakes in Nepal alone (Bolch et al., 2019).

**Sometimes called the Water Tower of Asia (Immerzeel et al., 2010), or of the World (Xu et al., 2008), the Third Pole cryosphere plays a critical role in regulating the water supply over a large region.** Glaciers and snowmelt supply key sources of dry-season water in the ten major river systems that originate in the HKH (Scott et al., 2019): the Amu Darya, Brahmaputra, Ganges, Indus, Irrawaddy, Mekong, Salween, Tarim, Yangtze and Yellow (Sharma et al., 2019). Cryospheric storage and dry-season release of water provide vital support for agriculture, hydroelectricity and drinking water (Nie et al., 2021). Over 240 million people live in the region's mountains; 1.7 billion live in the river basins downstream, while food grown in these river basins reaches 3 billion people (Sharma et al., 2019).

**Anthropogenic climate change has caused much of the Third Pole cryosphere to melt rapidly, with potentially far-reaching consequences.** With a few exceptions, the area and the volume of glaciers has steadily decreased throughout the region. **While the melting cryosphere of High Mountain Asia has far-reaching downstream impacts, this takes place in the context of larger changes.** The melting is driven by broader anthropogenic modifications of the atmosphere, and accompanied by broader impacts of these modifications. The Third Pole lies downwind from some of the most heavily polluted places on Earth. Air pollutants

**“While the melting Third Pole is very visible, with large downstream consequences, the impacts of other anthropogenic changes to the atmosphere might arguably lead to even more widespread human suffering”**

<sup>2</sup> Including Greenland.

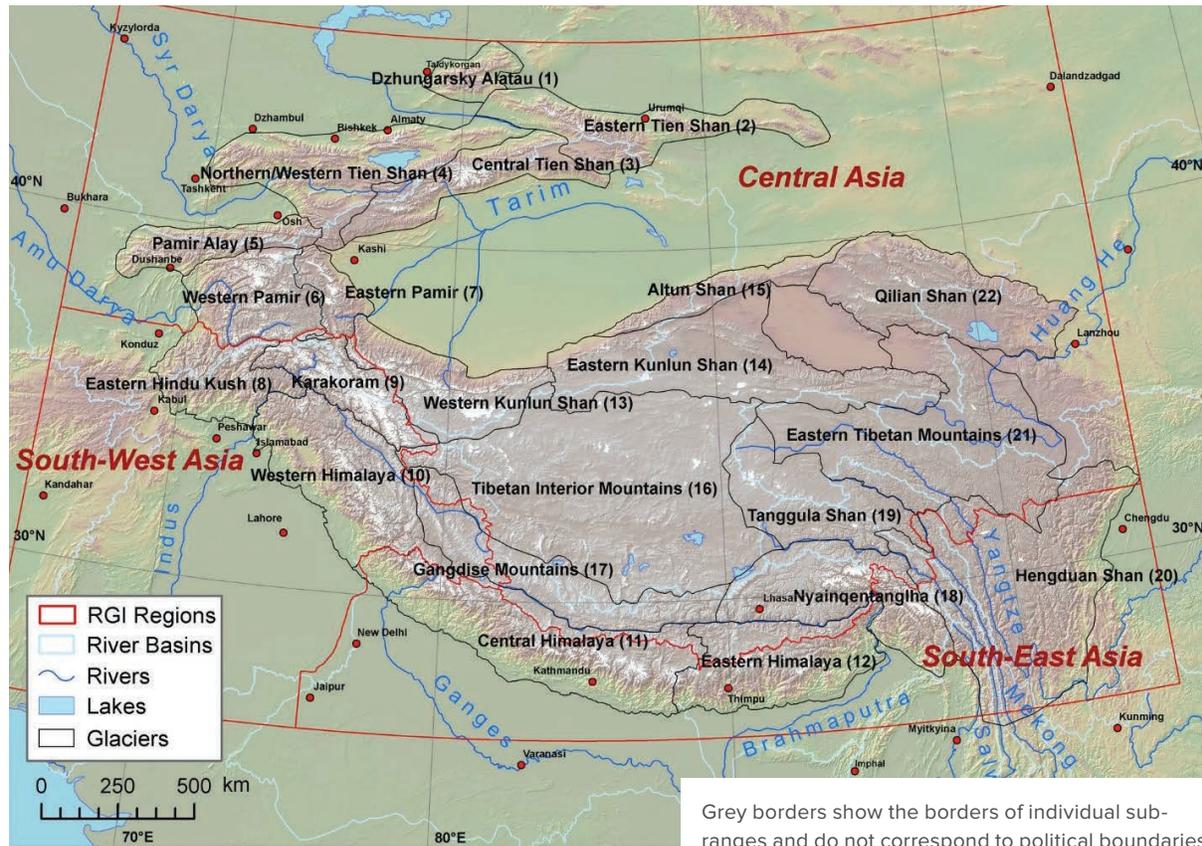
<sup>3</sup> While the origin of the term Third Pole is unclear, it obviously relates to the vast snow and ice that characterize the other two polar regions. The author himself does not like the term Third Pole, because a pole is the point of intersection between a planet and its rotational axis, which only exists at the North Pole and the South Pole, whereas this region spans across several thousand kilometers and does not sit anywhere near the axis of rotation. *The IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* uses the term *High Mountain Asia* for the same region. This policy brief will use the terms Third Pole and High Mountain Asia interchangeably. Incidentally, these same mountains also appear in the cryosphere chapter of *The Hindu Kush Himalaya Assessment* by Bolch et al. (2019), itself based on the classification in the Randolph Glacier Inventory (see <https://www.glims.org/RGI/index.html>) and consistent with the region considered by the Third Pole Environment program based in Beijing (see <http://www.tpe.ac.cn/webindex/>).

do not only threaten health, agriculture and the global climate, but they also contribute directly to changing precipitation and melting of the cryosphere. The monsoon system itself is also sensitive to climate change and air pollution.

The same solutions that will clean up the region’s air and dampen other aspects of climate change will also

protect High Mountain Asia’s cryosphere and prevent the disasters that are a direct result of its melting. Such solutions require coordinated actions from local to global levels (Box 1). **Protecting the cryosphere of High Mountain Asia, and addressing interrelated issues needs a broadening of attention beyond climate adaptation to ambitious mitigation.**

Figure 1: The individual mountain ranges of High Mountain Asia



Grey borders show the borders of individual sub-ranges and do not correspond to political boundaries  
Source: Wester et al. (2019)<sup>4</sup>

<sup>4</sup> Wester et al. (2019) has been published under the terms of the licensed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence and indicate if changes were made.

<sup>5</sup> Estimates of glacier area in the High Mountain Asia range from between 76,580 square km and 81,140 square km (Bolch et al., 2019) to 97,605 square km (Hock et al., 2019).

## THE NARROW STORY: A MELTING THIRD POLE AND ITS IMPACTS

This section summarizes current scientific knowledge on past, present and future changes in the Third Pole's cryosphere, and on the downstream impacts of these changes.

### OBSERVATIONS AND FORECASTS OF THE THIRD POLE CRYOSPHERE

**Atmospheric temperatures around the globe have increased rapidly in recent decades and are projected to continue rising.** A 140-year-old ice core record from a central Tibetan glacier shows several colder and warmer periods, with the strongest warming starting in the 1990s (Yang et al., 2008). Air temperature records from the Tibetan Plateau show significant warming beginning already in the 1950s (Liu and Chen, 2000), when global average temperatures remained relatively flat due to atmospheric dimming by heavy pollution in industrialized nations (Wild et al., 2007). Over the past two decades, temperature increases in High Mountain Asia have become more pronounced: Across the region, average temperatures increased by around 0.104°C per decade between 2001 and 2014 (Krishnan et al., 2019). By current projections, temperatures will continue to increase till mid-century, regardless of the climate scenario (Hock et al., 2019).

**Model simulations predict that even if global average temperatures stabilize at 1.5 °C above pre-industrial levels, at least 1.8°C of warming in the Himalaya and 2.2°C in the Karakoram will still occur** (Krishnan et al., 2019). Temperatures in High Mountain Asia are rising faster than almost anywhere else on the globe except in the Arctic and Antarctic. Elevation-dependent warming (EDW) has been observed across the Tibetan Plateau and the HKH, whereby the higher you go, the more rapid the increase in temperature.<sup>6</sup>

**Theory says that rising temperatures affect the cryosphere in several ways.** First, a larger fraction of precipitation falls as rain rather than snow, at a higher

altitude. Rain falling onto snow or ice surfaces causes rapid melting. With increasing average temperatures, the snow line<sup>7</sup> moves up, leaving progressively smaller snow 'islands' around the peaks. Finally, snowmelt already occurs earlier in the spring (Barnett et al., 2005).

**The region's extreme geographic diversity means that cryosphere impacts vary significantly, with some places becoming more vulnerable than others.** While the Himalaya receive four fifths of their snowfall during the summer monsoon, the Karakoram receive two thirds of their snowfall in winter as a result of westerly cyclones. The upper Indus Basin generally has more snow at lower elevations than the Himalaya (Bolch et al., 2019) and the glaciers in the Karakoram stretch down to lower elevations than in the Himalaya (Nie et al., 2021). Himalayan glaciers appear more sensitive to temperature increases because summer snowfall is more likely to turn into rain than winter snowfall (Bolch et al., 2012).

**With the exception of parts of the Karakoram, eastern Pamir and western Kunlun, High Mountain Asia has experienced widespread decreases in both the area and volume of glaciers in the past three decades** (Bolch et al., 2012; Nie et al., 2021). Glaciers in the Himalaya have been retreating since the mid-19th Century, although from the 1920s to the 1940s many remained stable. Glacial retreat accelerated in the 1990s (Bolch et al., 2012). Figure 2 represents the observed changes in glacier mass in different sub-regions pre- and post-2000, illustrating both the results and the limited availability of data.

<sup>6</sup> While data collection at high altitudes is sparse, it has firmly established EDW in the region. A variety of researchers have hypothesized mechanisms to explain EDW (Krishnan et al., 2019; Pepin et al., 2015). These mechanisms include:

- (1) The albedo effect, whereby a rising snow line and tree line decrease the surface reflectivity (compared to snow covered and bare surfaces), leading to absorption of more sunlight, greater heating of the surface and warming of the air.
- (2) An increase in elevation of the cloud condensation level (and thus an increase in the temperature at which cloud formation releases heat).
- (3) An increase in water vapor, thus increasing its greenhouse effect.
- (4) The elevated pollution layers that absorb sunlight (Bolch et al., 2019; Pepin et al., 2015).

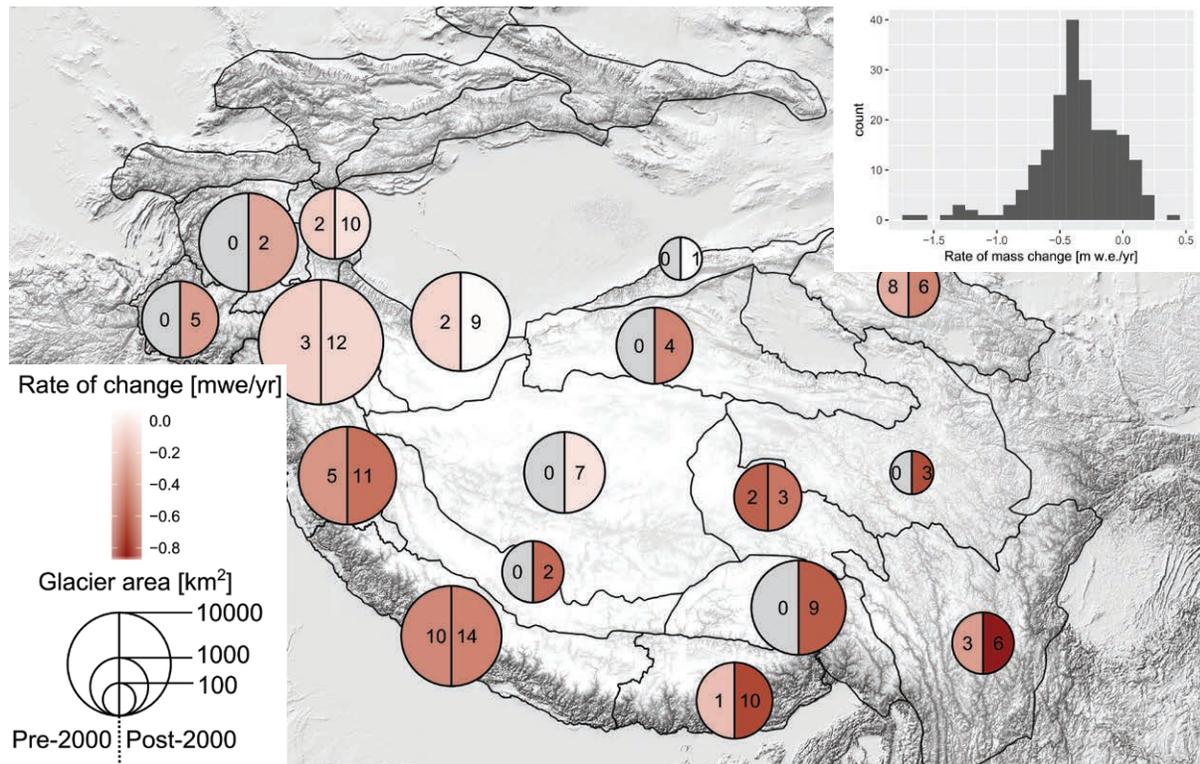
<sup>7</sup> The snow line is the altitude above which snow can persist year-round.

The glaciers of the Karakoram also receded from the 1920s and early 1990s, just like glaciers elsewhere in the world, but since the mid-1990s a number of large glaciers have surged forward (Hewitt, 2005). Individual glaciers in the Karakoram sometimes rapidly surge forward and retreat again (Bolch et al., 2019). The Karakoram region has experienced an increase in precipitation and a small decrease in summer temperatures (Hewitt, 2005), which may explain the surge in glaciers. However, the western disturbances that bring snowfall to the Karakoram have shown increasing variability (Krishnan et al., 2019). Other mountain ranges in High Mountain Asia, including the Hengduan, the Qilian, the Tien Shan, as well as the rest of the Pamir and Kunlun, have all seen reductions in both glacier mass and glacier area since around 1970 (Bolch et al., 2019).

Models forecast a loss of two-thirds of the HKH's glacial mass if current anthropogenic emissions trends continue (Bolch et al., 2019).<sup>8</sup> This model scenario (IPCC RCP8.5) assumes that economies will keep growing without significant greening. All modelled scenarios, regardless of emission assumptions, project continued loss of glacier mass in the near-term. All

also project accelerated deglaciation in the Karakoram (Bolch et al., 2019). By mid-century, model results diverge on the rate of melting, depending on which IPCC emissions scenario for greenhouse gases they assume. In the IPCC RCP8.5 scenario, the extended region will lose two thirds of its glacial mass, with the eastern Himalaya seeing a near total loss of its glaciers (Bolch et al., 2019). While a small hope exists that mitigation can achieve the Paris Agreement target of not exceeding a temperature increase of 2°C, the IPCC special report on the impacts of global warming of 1.5°C makes clear the enormous difference in impacts between global temperatures stabilized at 1.5°C versus 2°C above pre-industrial levels (IPCC, 2018). This has inspired climate activists around the world to aspire for a 1.5°C world. But this may not suffice for High Mountain Asia; *The Hindu Kush Himalaya Assessment* points out that even if global average temperatures stabilize at 1.5°C above pre-industrial levels, High Mountain Asia would still likely lose one third of its glacier mass by the end of the century, with the Himalaya losing half of its glacier mass (Bolch et al., 2019; Wester et al., 2019).<sup>9</sup>

Figure 2: Changes in glacier mass in different subregions



Note: The circle size represents the glaciated area; the colour denotes the rate of change in meter water equivalent (MWE) per year pre-2000 and post-2000. Numbers inside the circles denote the number of studies available pre- and post-2000 for that region. Source: Wester et al. (2019)

<sup>8</sup> This assumes IPCC scenario RCP8.5.

<sup>9</sup> There is some uncertainty in these projections: IPCC attaches medium confidence to the prediction of magnitude and timing of glacier losses in future climate scenarios, but, as pointed out earlier, a 1.5°C increase in global average temperature would result in higher temperatures in High Mountain Asia (Hock et al., 2019).

**Glaciers are not the only shrinking part of the cryosphere. Seasonal snow cover has also decreased.**

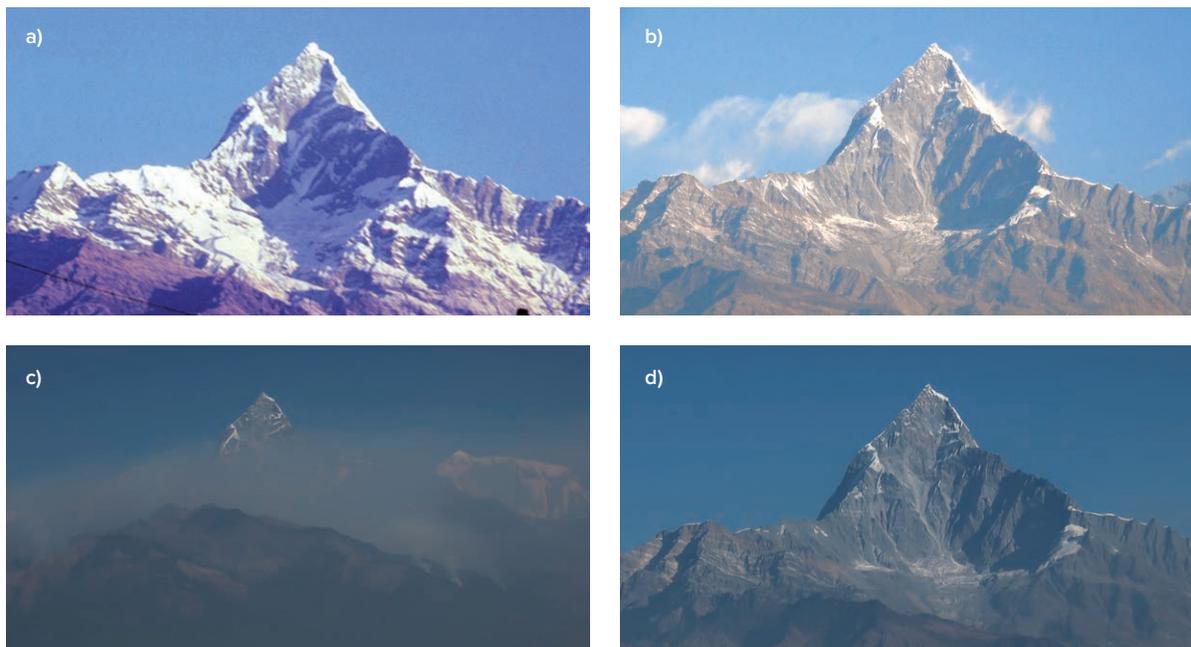
While snow cover has strong interannual variability, it has clearly decreased at lower elevations, where precipitation has switched from snow to rain (Hock et al., 2019). The snow line – the altitude above which snow persists year-round – has gradually shifted to higher altitudes, leaving smaller areas snow-covered. Shrinkage of snow-covered areas and snow volume will likely continue in the coming decades in response to warming, with the snow line continuing to climb to higher elevations (Bolch et al., 2019). Figure 3 shows the loss of both glacier and snow cover on a prominent Himalayan peak.

**A decrease in snow cover causes further climate impacts.** The amount of snow on the Tibetan Plateau affects the plateau’s reflectivity, and thus its surface heating and the strength of the low pressure that forms over the plateau. This has a strong impact on atmospheric circulation and on the Asian monsoon (Bolch et al., 2019).<sup>10</sup> Reduction in snow cover also creates a local feedback: When snow disappears from a

small patch to reveal darker rock underneath, the surface albedo (reflectivity) decreases and the dark rock absorbs more sunlight. This warms up the air above the dark rock, which comes into contact with nearby snow, melting it even faster.

**The region’s permafrost has also decreased,** although fewer studies have documented this. Large portions of the Tibetan Plateau and high-altitude sections of the region’s mountains have soil-water in frozen rather than liquid form. Below a certain depth, this remains frozen all year around, but near the surface, in places where summer temperatures rise above freezing, the uppermost soil layers thaw seasonally. Rising temperatures will likely thaw these soils to greater depths (Bolch et al., 2019).<sup>11</sup> In places with infrastructure built on top of permafrost, such as the highways and railroads on the Tibetan Plateau, thawing of soils can create undulations and other damage. Melting permafrost on steep slopes can trigger landslides and rockfalls (Hock et al., 2019); if these fall onto glacial lakes they can create waves that breach the moraines holding back the lakes (Bolch et al., 2019).

**Figure 3:** Mt. Machapuchare in the Annapurna Himalaya in 1973 (a), 2011 (b), and at present (c,d)



Note: In (c) massive high altitude forest fires obscured the views of the peak on 31 December 2020, while (d) shows the peak the next morning on 1 January 2021. Note that the glacier seen in the mountain’s lap in 1973 has already been lost for more than a decade. Photos by (a) Fritz Berger; (b) Arnico Panday; (c) (d) Ananya Panday

<sup>10</sup> Teleconnections like this are common: The 2010 floods in Pakistan were connected to a heatwave in Russia, while the monsoon is also connected to Atlantic Multidecadal Oscillation (Lau and Kim, 2012; Wang et al., 2009).  
<sup>11</sup> Mountain permafrost contains less soil carbon than Arctic permafrost, so its melting might have less feedback on climate than the melting of the Arctic Tundra, which would release large amounts of methane into the atmosphere (Hock et al., 2019).

**As glaciers have receded across the region, the number of glacial lakes has grown.** Glacial lakes can grow rapidly, often held back by unstable moraine dams. When a moraine dam fails, a catastrophic glacial lake outburst flood (GLOF) drains the entire lake down the valley. 65 GLOFs have been recorded in the Himalaya since 1930 (Nie et al., 2021). GLOFs have destroyed roads, trails, houses, fields, hydropower plants and lives, as happened during the Dig Tsho GLOF in Nepal in 1985 (Hock et al., 2019).<sup>12</sup> Some glacial lakes in the region have grown rapidly, causing alarm (Fujita et al., 2009). While no consensus has yet arisen about whether data show an increasing occurrence of GLOF events in recent decades, there *is* consensus that the growth in number and size of glacial lakes increases the risks for the future (Nie et al., 2021). 21 dangerous lakes have been identified in Nepal and 52 in India (Bolch et al., 2019). Emergency action averted a potential GLOF from Tso Rolpa Lake in Nepal in 2000, by

constructing a siphon and an open channel that allowed a reduction in the lake's water level (Pokharel, n.d.).

**The Third Pole is not unique.** In mountainous regions around the world, the cryosphere is melting. Observations confirm alarming and ongoing decreases in the cryosphere from the Antarctic through the Andes, the Caucasus, the East African Highlands, the European Alps, New Zealand Alps, the Rockies, and Scandinavian and north Asian mountains (Hock et al., 2019). The melting rates in High Mountain Asia are higher than the global average, but not overwhelmingly so. **The difference from other mountainous regions is that the Third Pole contains a larger volume of frozen water, and the changes here affect a far larger number of people.**

## DOWNSTREAM AND HUMAN IMPACTS OF A MELTING THIRD POLE

**A warming Third Pole, with a retreating cryosphere, affects water availability in the rivers downstream.** Already by 2005, the HKH and its downstream river basins had caught attention as the global region where retreating glaciers would most critically affect water supply in the coming decades (Barnett et al., 2005). While changes in annual precipitation affect the annual total amount of water available in a basin, temperature change affects the fraction stored in frozen form rather than running off, and thus impacts the timing of water availability (Barnett et al., 2005). In basins with a cryosphere fed by winter snow, warming temperatures lead to the spring peak flow shifting to earlier in the season (Bolch et al., 2012).

**The level of dependence on the cryosphere depends on the river basin.** Rivers can have four potential sources of water: snow melt, glacier melt, rainfall and groundwater. Their proportional contributions vary at each point along a river, as well as in time (Shrestha et al., 2015). In the mountainous upper reaches of river basins, a large fraction of the water in streams and rivers might originate from the melting snow and glaciers. This fraction shrinks as one travels down the length of a river and more rain-fed tributaries join

it (Bolch et al., 2012). The dependence on the cryosphere varies among river basins; for example, while only 9 percent of the water reaching the delta of the Ganges originates in glaciers and snow, the Indus river flows through a much more arid region, collecting far fewer rainfed tributaries: 78 percent of the water at the mouth of the Indus originates in the cryosphere, including 46 percent from snow and 32 percent from glaciers (Immerzeel et al., 2010; Scott et al., 2019). In fact, the Indus Basin is the second most water-stressed basin in the world (Shrestha et al., 2015).

**Climate changes and retreating glaciers affect water availability in several ways.** As a glacier recedes and thus reduces its store of frozen water, it sends more water into the river downstream earlier in the spring. However, as the glacier shrinks further, there comes a point when that process slows down and less water becomes available (Hock et al., 2019). While glacial water has already declined in some areas in the world with small cryospheres, the contribution of the Himalayan cryosphere to rivers will likely peak in the 2040s (Hock et al., 2019). The seasonality of cryospheric impacts on river water also varies: Monsoon-fed tributaries of the Ganges and Brahmaputra will continue

<sup>12</sup> Note that the Kedarnath disaster in India that killed several thousand in 2013 resulted from a landslide damming a stream, creating a lake that then burst out, and not from a GLOF as occasionally reported (Shrestha et al., 2015); see <https://www.downtoearth.org.in/news/what-really-happened-in-uttarakhand-41550>.

to experience their peak flows during the summer, regardless of whether they receive less water from shrinking glaciers in the spring. In contrast, warmer winter temperatures and less snow in the Karakoram will have a bigger impact on the Indus River’s peak flow in the spring (Bolch et al., 2012). As the amount of water storage in the cryosphere shrinks, however, river basins become more dependent upon highly variable monsoon rainfall (Nie et al., 2021).

**The changing water availability due to a shrinking cryosphere has wide-ranging impacts on economies and livelihoods.** In the Himalaya, decreasing water availability in the dry spring months will increasingly affect hydropower production during what has already become the most challenging season (Scott et al., 2019). In fact, across the region, 15 percent to 40 percent of hydropower production depends on glacial meltwater during the dry season (Nie et al., 2021). While few studies have examined the economic impacts of this dependence in High Mountain Asia, a study in Peru found losses of US\$ 5 million per year from the reduction of water to the operator of the Cañón del Pato hydropower plant, resulting in a loss of \$20 million per year for the broader economy (Hock et al., 2019). In addition to changing water availability, glacier retreat and moraine erosion change the silt load in rivers, potentially filling reservoirs faster (Hock et al., 2019).

**Changing water availability in rivers due to a shrinking cryosphere affects agriculture in certain regions.** Scientists have projected reduced productivity in irrigated agriculture in the Indus basin, as well as in some other high mountain areas (Hock et al., 2019). Parts of northern Pakistan and Ladakh have irrigation systems that depend solely on glaciers and snowmelt (Scott et al., 2019). For high mountain pastures and farms, less

winter snow cover means less soil moisture (Hock et al., 2019). Rainfed terraced farms on hill slopes are less affected by changes in the cryosphere, but fields in the valley bottoms might see impacts if their irrigation depends on large snow-fed rivers. In India and Pakistan, more than 100 million farmers depend upon irrigation water coming directly from the Indus and Ganges Rivers rather than from their tributaries (Hock et al., 2019).<sup>13</sup> In many places, glacial meltwater provides critical protection during droughts, when other water sources fail; this has proven particularly important in the Indus and Tarim Basins (Nie et al., 2021).

**A shrinking cryosphere affects availability of drinking water, not just in villages immediately below glaciers, but also in certain far-away cities.** Sporadic reports of decreased access to drinking water have come out of Nepali villages that rely directly on glacier-fed streams (Hock et al., 2019). Andean cities, meanwhile, have received significant attention that may prove relevant; for example, during droughts, 80 percent of La Paz’s water supply comes from glacial runoff. Kathmandu in Nepal, a Himalayan metropolis with more than 4 million inhabitants, is about to solve its shortage of rainfed water via a tunnel project to import water from the Melamchi River, and in the second phase from the Indrawati watershed; however, this means increasing its future dependence on a shrinking cryosphere (Mandal, 2021).

**A melting cryosphere affects biodiversity and tourism.** As temperatures increase, lowland species shift their ranges uphill, while upland species become confined to a smaller and more fragmented range in shrinking ‘islands’ around the peaks (Hock et al., 2019). Tourism will also see impacts, not just in the closure of the small number of ski resorts in the region (in Kashmir, Kyrgyzstan and Tajikistan), but also because many other tourism products in the region, including trekking, depend on selling vistas of snow-covered mountains, such as those in Figure 3.

**While no evidence has appeared of increased frequency of GLOF occurrences in recent years, rapidly retreating glaciers will allow the growth of many new potentially dangerous glacial lakes in the coming decades,** including lakes that do not yet exist (Hock et al., 2019). With the building of more dams, diversions, hydropower plants, bridges, roads and valley-bottom settlements, the likelihood increases of a GLOF causing costly damage and high casualties.

“The melting of the Third Pole is closely connected to the same human activities and drivers that are also polluting the region’s air, driving global climate change and raising sea levels”

<sup>13</sup> Note that many residents in the Ganges Basin depend on pumping ground water, with an estimated 20 million pumps (Scott et al., 2019).

**Box 1:** Summary of problems and solutions

**Current global emission trends are disastrous for High Mountain Asia, and would result in a loss of two-thirds of all glacier mass by the end of the century, accompanied by a range of other interconnected problems.**

The Paris Agreement’s target of stabilizing global average temperatures at less than 2°C above pre-industrial is insufficient to protect the snow and ice of High Mountain Asia. In fact, **even stabilizing the global average temperature at 1.5°C will be too warm, as that will still cause a warming of 1.8 to 2.2°C in High Mountain Asia, resulting in a loss of a third of the region’s glacier mass by the end of the century.**

Investment in adaptation to the changing water availability due to Third Pole melting, and to broader impacts of climate change, will do much to protect the most vulnerable people and nations, but **adaptation alone is insufficient.**

The melting of glaciers and snowfield of High Mountain Asia is driven by the global increase in greenhouse gases as well as by black carbon and other pollutants of regional origin. The same phenomena also drive the region’s air pollution problem and changes in the monsoon. **The shrinking of the glaciers and its**

**impacts are not an isolated disaster, but a symptom and a symbol of a broader problem with how humans treat the atmosphere.**

To save High Mountain Asia’s glaciers, clean up the region’s air, protect the monsoon system, and address climate change on a global level, **the world’s economy urgently needs to draw down greenhouse gases. It needs to stop using fossil fuels and also reduce emissions of black carbon and other short-lived air pollutants.** This calls for shifting billions of people to clean cooking and heating, bringing about major changes in agricultural practices and diets, and massively reducing open fires. It also requires a rethinking of urban spaces and promoting sustainable walkable cities.

**The United Nations Development Programme (UNDP) itself can play a major role,** setting an example at its offices, educating politicians and voters about responsible leadership, and obtaining pledges from big technology firms.

Protection of High Mountain Asia’s snow and ice can become a unifying and politically neutral goal around which to build international cooperation and collaboration during the challenging decade ahead.

## RESPONSE ONE: IMPROVED ADAPTATION AND DISASTER RESILIENCE

As we just saw above, **even in the best-case scenarios, High Mountain Asia will lose a substantial part of its cryosphere in the next decades and thus a substantial part of its water storage abilities, resulting in increased water stress** in high mountain areas, along with impacts on agriculture, hydropower, and drinking water in cryosphere-dependent river basins. The risk of GLOFs will persist and perhaps increase in the coming decades. At the same time, as we will show below, a changing climate will cause more extreme events in the monsoon, resulting in additional floods and landslides. Consequences of cryospheric melting will

become part of a larger picture of how a changing atmosphere and climate will negatively impact people’s wellbeing.<sup>14</sup> **We have no choice but to adapt to the changing world to protect the lives and livelihoods of the vulnerable.**

**Policies and actions must address the needs of key stakeholders affected by water stress, whether caused directly by a shrinking cryosphere, or by changing precipitation patterns.** These include mountain farmers: water scarcity can seriously impact small-holder subsistence farmers, and it has links to the de-

<sup>14</sup> For example, many springs in the HKH foothills have dried up for reasons unconnected to the cryosphere (Scott et al., 2019).

pletion of local water sources, deforestation, increased demand from growing populations, increased competition for access, and problems with affordability, as well as water quality (Shivakoti et al., 2014). People in High Mountain Asia have responded to increasing water stresses in several ways. Some have switched to crops that need less water; some have adopted new irrigation technologies – for example, an engineer in Ladakh invented “ice stupas” to store water in frozen artificial glaciers (Hock et al., 2019). **Farmers will need support to design and invest in locally-appropriate water storage solutions, or to shift to agricultural practices that consume less water.**

**Hydropower producers will need to adapt.** A shrinking cryosphere will affect the availability of water in rivers, in some cases shifting and increasing early spring run-off, and in other cases reducing dry-season water availability. The amount of silt in the rivers will also change. While existing hydropower plants may have fewer available solutions and more difficulty recouping investments, **designs of new hydropower plants and grids will need to take into account the changing climate and water availability.**

**Infrastructure design will need to accommodate larger floods.** Designs of hydropower projects, roads and bridges will also need to take into account the existence of current or potential future glacial lakes upstream, and the potential size of a GLOF. Even on slopes and valleys not at risk for GLOFs, more extreme rainfall will require larger storm drains and more attention to slope stability. All of this calls for surveys, calculations and additional engineering capacity these. While in some cases, siphoning off glacial lakes can mitigate the risk of GLOFs, it will not be possible to avoid disasters altogether.

**Disasters caused directly by cryospheric change will comprise a small fraction of the disasters occurring in the region, but all need better preparedness.** High Mountain Asia faces disasters of many kinds, from low-frequency earthquakes to high-frequency landslides, floods and coastal storms (Vaidya et al., 2019). Most floods occur during the monsoon season and

have no direct connection to the cryosphere. While dozens of Glacial Lake Outburst Floods have been recorded, some with heavy losses of lives and infrastructure, their overall impacts amount to a small fraction of those created annually through monsoon-induced floods and landslides (Bolch et al., 2019; Vaidya et al., 2019). Cryosphere-induced disasters need the same sort of preparation as others: early warning systems, infrastructure designed to withstand low-probability-high-loss events, emergency services trained and on stand-by, as well as institutional mechanisms in place to support victims in rebuilding their lives. The latter has special importance in mountain areas, which have a higher incidence of poverty than the plains (Wester et al., 2019). In many places, vulnerability to other impacts of climate change (precipitation, temperature and their impacts on livelihoods) will exceed those triggered by cryospheric changes.

**One key priority is the protection of the most vulnerable.** Climate change exposure is one of several vulnerabilities in the mountains; adaptive capacity depends on many non-climatic factors, including poverty, but also policies, institutions and processes (Gioli et al., 2019). Societies and individuals in the mountains have considerable practice in adapting to variability, and farmers appear to have already begun changing their practices. However, concern remains that they will have limited ability to tackle the newly-emerging ‘surprise’ challenges of accelerating climate change (Mishra et al., 2019).

**Improving adaptation requires data and information, capacity-building and early warning systems, as well as better designed infrastructure. This calls for sufficient funding and large-scale coordination.** Countries in the region have begun to follow their National Adaptation Plans via policies and budgeting that focus on current and immediate threats (Mishra et al., 2019). They still require longer term thinking, including investments in redundancy in infrastructure networks.<sup>15</sup> Many impacts of the cryosphere and climate change extend across national borders. While the International Centre for Integrated Mountain Development (ICIMOD), an intergovernmental learning and knowledge-sharing centre for the HKH region, has piloted a small number of cross-border flood early warning systems, no formal agreement or mechanism for regional collaboration on climate change adaptation exists today for the broader High Mountain Asia region (Prabhakar et al., 2018). These structures urgently need creation, alongside increased investment and cross-border collaborations on data collection and monitoring (Nie et al., 2021).

<sup>15</sup> For example, to make sure that access remains possible even if a bridge or a stretch of road is damaged.

## THE BROADER STORY WITH THE SAME DRIVERS: AIR POLLUTION, MONSOON CHANGE AND THE GLOBAL CLIMATE

In this section, we examine the main drivers of the melting Third Pole and their broader impacts, including increases in atmospheric concentrations of long-lived greenhouse gases and short-lived climate pollutants, due to human activities.

### THE DRIVERS OF ATMOSPHERIC CHANGE: GREENHOUSE GASES AND SHORT-LIVED CLIMATE POLLUTANTS

**The global increase in both long-lived greenhouse gases and short-lived climate pollutants drives the melting of the cryosphere. Globally, the biggest driver of warming is carbon dioxide (CO<sub>2</sub>).** Since the mid-1800s, atmospheric CO<sub>2</sub> levels have increased by almost 50 percent due to two human activities: the burning of fossil fuels, which transfers to the atmosphere carbon that was stored underground for millions of years; and large-scale deforestation, which transfers to the atmosphere carbon that was stored in the biosphere (Hawken, 2017). With an atmospheric lifetime of 100+ years, CO<sub>2</sub> is well-mixed<sup>16</sup> around the globe. Its impacts thus do not depend on its source or source region and will also persist even after emissions reduction. Along with other greenhouse gases (methane, nitrous oxide, ozone, sulphur hexafluoride and various hydrofluorocarbons [HFCs]), CO<sub>2</sub> warms the atmosphere by absorbing outgoing infrared radiation, and radiating some of that back to the surface.<sup>17</sup>

**Globally, the second biggest contributor to warming is black carbon (BC),** which is emitted into the atmosphere during incomplete combustion in the form of fine charred particles (Bond et al., 2013). BC warms the atmosphere by absorbing incoming sunlight. When present in elevated atmospheric layers, it warms them, reducing the sunlight reaching the land surface (Ra-

manathan and Carmichael, 2008; Tripathi et al., 2007). This can cause local dimming of up to 10 to 20 Watts per square meter (Streets et al., 2006; UNEP/WMO, 2011). BC has an atmospheric lifetime of days to weeks; much of it thus remains concentrated in a handful of heavily polluted regions. High Mountain Asia is near three of the world's five regions with the heaviest BC loads: East Asia, South Asia (particularly the Indo-Gangetic Plains) and Southeast Asia (Gertler et al., 2016). Along with the greenhouse gases methane, ozone, and HFCs, **BC is classified as a short-lived-climate pollutant (SLCP).** Because of SLPCs' short atmospheric lifetimes, their mitigation yields rapid climate results, while also giving other co-benefits (UNEP, 2011). In fact, mitigating SLCPs globally will provide a one-time reduction in warming of up to 0.5°C (IPCC, 2018; Shindell et al., 2017).

**Along with wind-blown dust, BC also helps melt the cryosphere in a second way:** when BC deposits onto white snow or ice surfaces,<sup>18</sup> it darkens those surfaces, increasing the absorption of sunlight and accelerating melting (Gertler et al., 2016; Yasunari et al., 2010).<sup>19</sup> Although less dark than black carbon, desert dust can play a similar role. Snow darkening by wind-blown dust particles from the Thar Desert has been observed high in the Himalaya (Gautam et al., 2009; Saikawa et al.,

<sup>16</sup> When a gas is 'well-mixed' its concentration varies very little over long distances.

<sup>17</sup> This is similar to the way glass panes on a greenhouse keep the interior warmer or the way a blanket keeps a person warm at night.

<sup>18</sup> Absorption of sunlight by dark particles plays a bigger role in melting snowfields and white glaciers than it does in melting Himalayan glaciers covered by debris (Bolch et al., 2019).

<sup>19</sup> Each particle of black carbon plays a similar role to that seen when the sun shines onto a leaf that has fallen onto the snow: while the snow around it reflects most of the sunlight, the darker leaf or the darker particle absorbs the sunlight, heats up, and melts the snow underneath, sinking into the snow.

2019), while dust from the Taklimakan Desert in the Tarim Basin reaches the Kunlun Mountains and the northern Tibetan Plateau (Xia et al., 2008). Figure 4(a) shows an elevated atmospheric layer of particles in the Himalaya, while Figure 4(b) shows darkened slopes

explicable only by the deposit of dark particles. Bare surfaces left behind by retreating glaciers provide additional sources of dust that may blow onto what remains of the glaciers, accelerating their melting (Hock et al., 2019).

**Figure 4:** Haze layer reaching high altitudes in the Annapurna Himalaya (a), Snow darkening by deposited particles distinctly visible in the Kanchenjunga Himalaya (below the red line drawn onto the photo) (b)



Photos by Arnico Panday

**The Indo-Gangetic Plains (IGP) are one of the biggest sources of particles reaching High Mountain Asia** (Kang et al., 2019; Saikawa et al., 2019). With a population of close to 800 million, these fertile plains contain many of the world's most polluted cities as well as heavily polluted rural areas (Saikawa et al., 2019; Chen et al., 2020; Rupakheti et al., 2017; Wan et al., 2017). Figure 5 shows a satellite image of a typical winter day,

with the ground of the IGP barely visible through the haze. The atmosphere above the IGP has warmed at a rate of 0.25°C per decade, while the surface has dimmed and cooled (UNEP, 2019). On Yala Glacier in Langtang, Nepal, 56 percent of BC was identified as fossil-fuel in origin – much of it from the plains of Nepal and India, but with occasional increased atmospheric BC concentrations from nearby forest fires (Gul et al., 2021).

**Figure 5:** Gray haze covering the Indo-Gangetic Plains on 4 December 2020

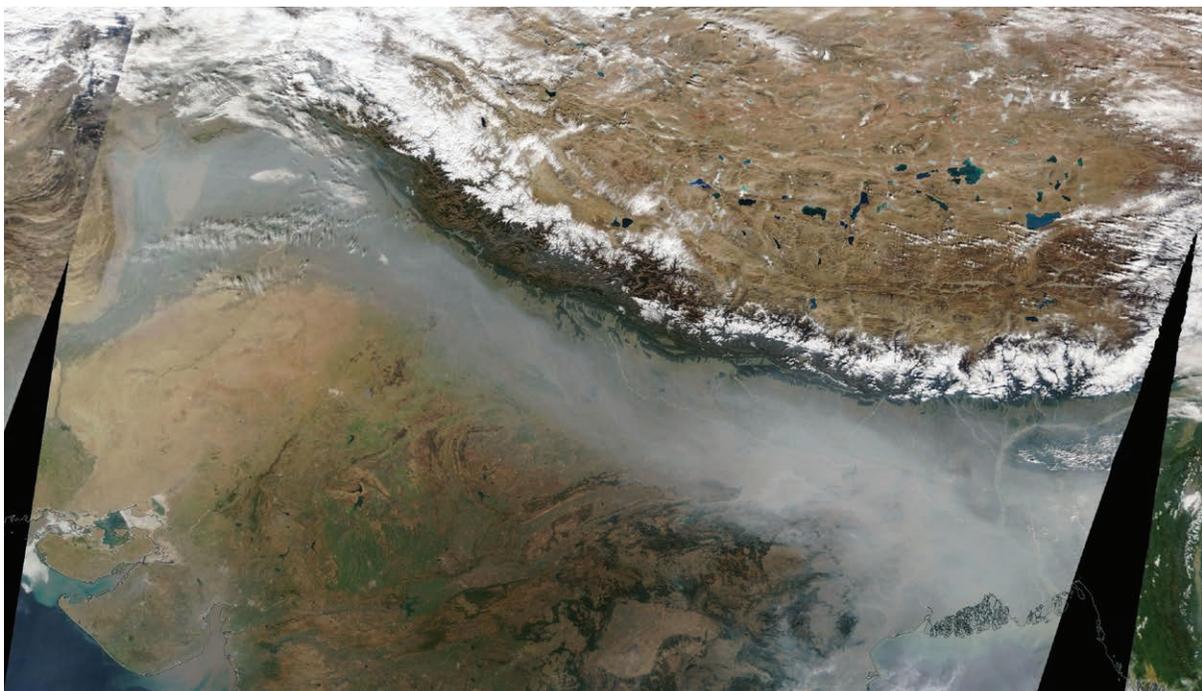
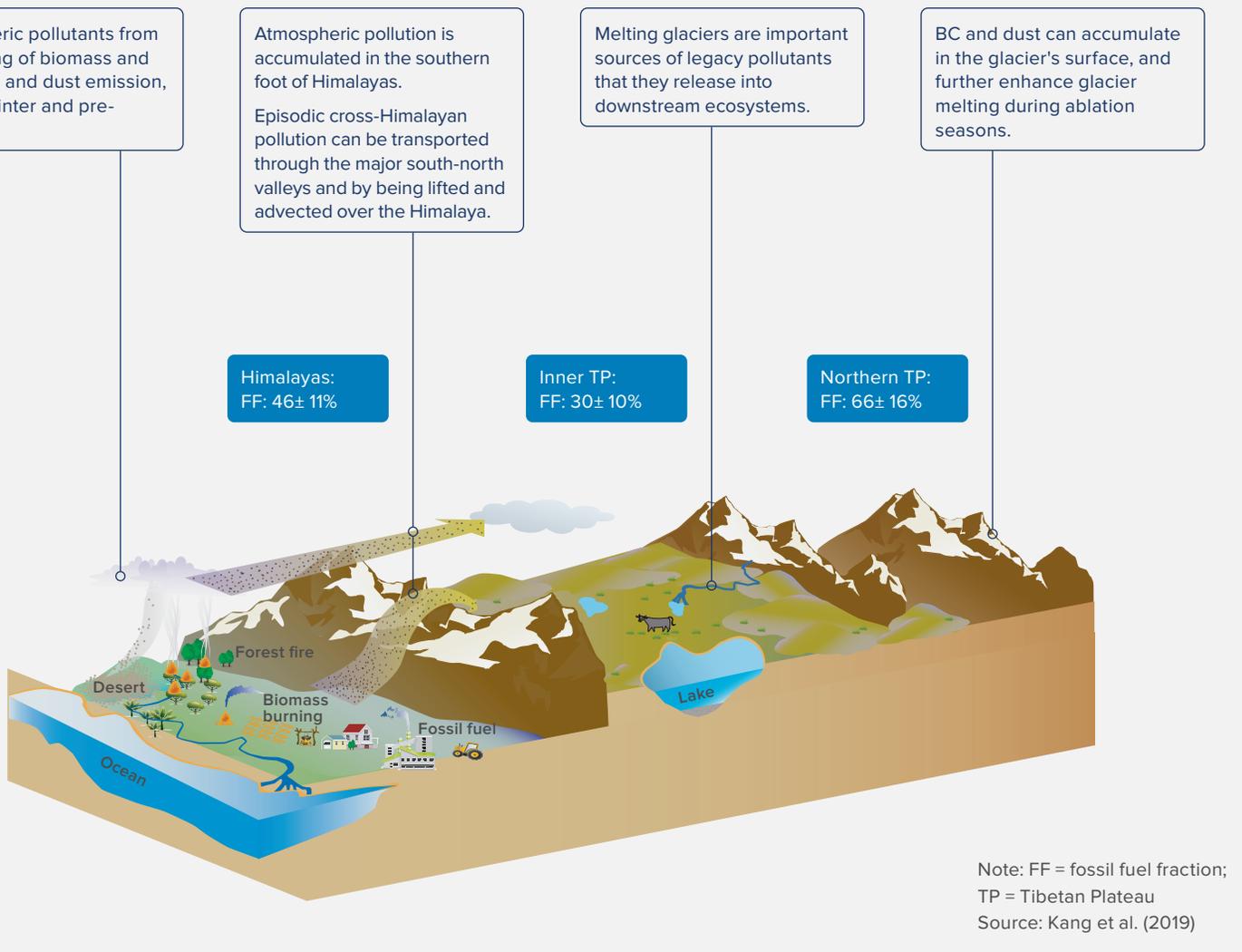


Photo by Arnico Panday from NASA (2020)

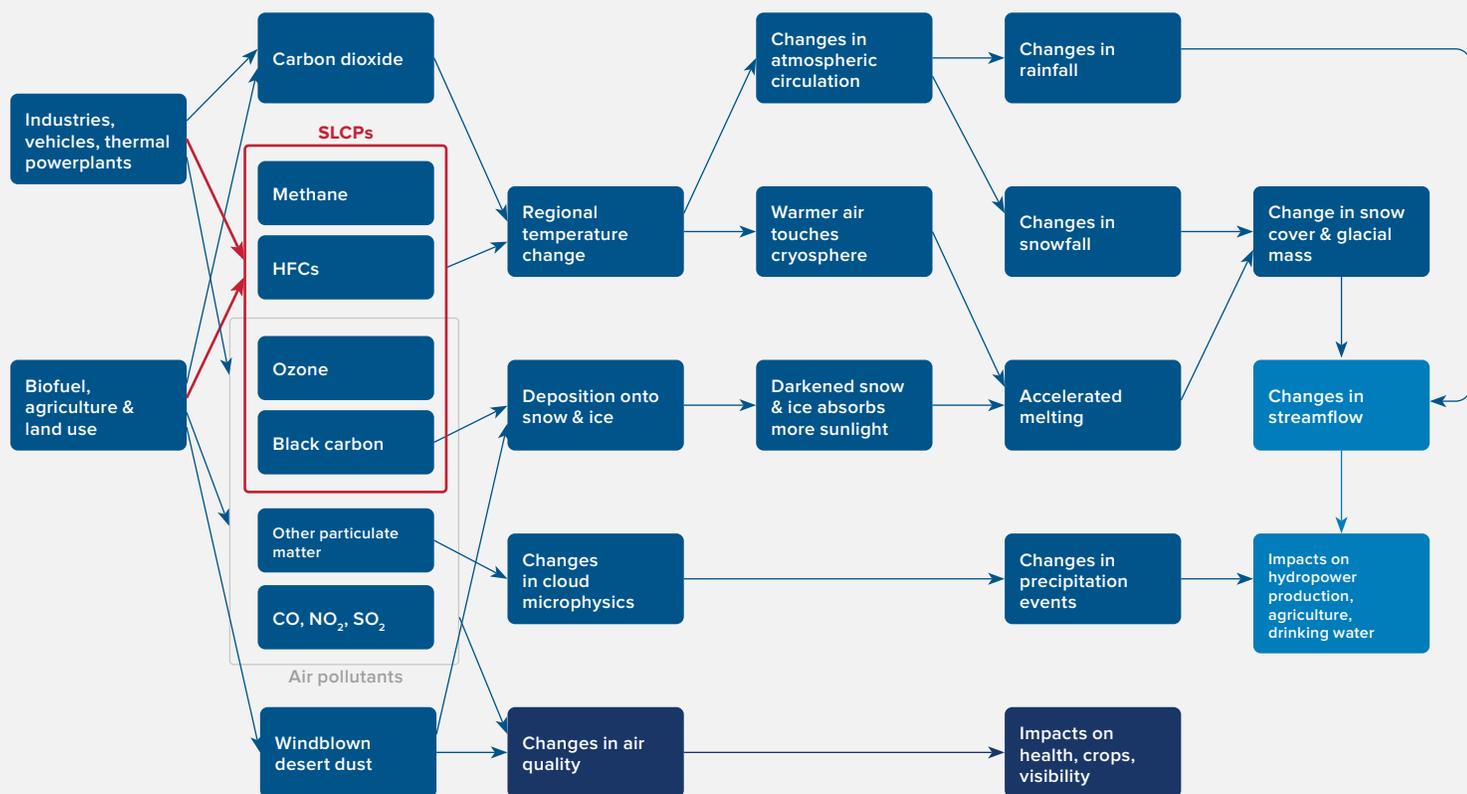
**Figure 6:** Processes responsible for the transport of black carbon pollutants from the Indo-Gangetic Plains across the Himalaya to the Tibetan Plateau, along with its impacts



Although the Himalaya are the tallest mountain range in the world, they are within reach for pollutants from the IGP, and they also do not block the transport of pollutants over to the Tibetan Plateau. High levels of black carbon have been recorded at 5 km altitude in the Nepal Himalaya, in the Karakoram and on the Tibetan Plateau (Gul et al., 2021; Marinoni et al., 2010; Rai et al., 2019; Chen et al., 2019; Cong et al., 2009; Saikawa et al., 2019). Pollutants from the IGP reach the Tibetan Plateau along several pathways. They can cross through deep valleys such as the Arun and the Kali Gandaki or at high altitude during favourable weather conditions (Brun et al.,

2011; Dhungel et al., 2018; Kang et al., 2019; Lüthi et al., 2014; Xia et al., 2011). Figure 6 illustrates some of the processes responsible for the transport of pollutants from the IGP to the high Himalaya and on to the Tibetan Plateau. From 1996 to 2010, the BC on the Tibetan Plateau from outside sources increased by 41 percent (UNEP, 2019). Figure 7 illustrates the **complex interplay between processes that lead to the melting of the cryosphere, along with its direct and associated impacts**. Details are provided in the Figure 7 notes.

Figure 7: Interrelationship of drivers of cryospheric melting with other processes and impacts



Source: Author

Industries, vehicles, household energy, and agriculture all contribute to increased emissions of carbon dioxide, short-lived climate pollutants (SLCPs) and other air pollutants. Increased atmospheric concentrations of carbon dioxide and SLCPs contribute to increases in the regional temperature. When warmer air touches frozen surfaces, this accelerates their melting. Addi-

tional melting occurs when black carbon particles as well as windblow dust settle on snow and ice surfaces, darkening them, absorbing more sunlight, and accelerating the melting as well. Temperature changes also affect atmospheric circulation, which affects precipitation. Meanwhile, air pollutants co-emitted by the same sources affect air quality and health.

## ASSOCIATED IMPACTS OF THE SAME DRIVERS: AIR POLLUTION AND MONSOON CHANGES

The combustion sources responsible for the BC emissions that reach the High Mountain Asia cryosphere, as well as for the region's CO<sub>2</sub> emissions, also have other, arguably larger impacts on human health and wellbeing.

**Widespread cooking and heating with solid fuels, poorly-maintained vehicles and industries, as well as widespread open fires produce some of the worst air quality in the world in the regions upwind of High Mountain Asia.** In South Asia, outdoor fires plus

cooking with biomass may contribute more than half of atmospheric BC (Gustafsson et al., 2009). 50 out of 51 cities around the HKH in the World Health Organization (WHO) database have annual average levels of fine particulate matter (PM2.5) exceeding WHO guidelines. Among these cities, a dozen exceeds WHO standards for annual average concentrations more than tenfold, including New Delhi (Figure 8a) (Saikawa et al., 2019). These levels have immense health impacts in cities, especially for the most exposed populations, such as street vendors, traffic police, and others who spend considerable time on the street (Gurung and Bell, 2012; Shakya et al., 2017). In fact, the highest average levels of PM2.5 exposure in the Asia-Pacific are in Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan (UNEP, 2019).

tions in rural Uttar Pradesh, Chitwan and Lumbini have found pollution levels comparable to those in very polluted cities, indicating that hundreds of millions of people on the IGP face exposure to very unhealthy air (Praveen et al., 2012; Mehra et al., 2018; Rupakheti et al., 2018; Rupakheti et al., 2016; Wan et al., 2017). During the dry season, emissions from millions of local pollution sources across the IGP merge into a thick haze layer that can last for months and extend up into the mountains (Figure 5 and Figure 8b and c). This has consequences for local climate and visibility (Dey and Girolamo, 2010; Gautam et al., 2010; Di Girolamo et al., 2004; Praveen et al., 2012; Saikawa et al., 2019). The reduced sunlight and poor air quality have also led to significant impacts on agricultural productivity (Auffhammer et al., 2006; UNEP, 2019).

**Poor air quality is not limited to large cities.** Observa-

**Figure 8:** Haze obscuring aerial view of New Delhi during November 2014 (a), view of Kathmandu on a clear day 28 February 2013 (b), same view two days later, on 2 March 2013, with regional haze present (c)



Photos by Arnico Panday

**One particular concern arises from the high level of indoor air pollution to which women and children are exposed in households using solid fuels for cooking and heating.** Indoor combustion of solid fuels is also a very large source of outdoor pollution. 1.9 billion people in Asia and the Pacific use solid fuels for cooking and heating (UNEP/WMO, 2011). Figure 9 shows the death rate due to air pollution in countries of Asia-Pacific. Almost two thirds of the 7 million annual premature deaths attributed to indoor and outdoor air pollution globally take place in Asia, mostly in the countries surrounding High Mountain Asia (UNEP, 2019).

**Air pollution in the region has started to alter the region's meteorology, affecting monsoon precipitation.** Airborne particulates change rainclouds by affecting the number and size distribution of cloud droplets, which can delay and then intensify a rain event.<sup>20</sup> In recent years, scientists have found direct ties between heavy precipitation events and air pollution impacts on cloud properties (Cho et al., 2016; Choudhury et al., 2020). Meanwhile, light-absorbing particles also change atmospheric heating patterns, affecting the timing and location of where convective clouds form (Gautam et al., 2010; Lau and Kim, 2006; Lau et al., 2006). Despite the complicated interaction of these processes,<sup>21</sup> increasing evidence suggests that air pollution is responsible for a weakening of the South Asian summer monsoon (UNEP, 2019). Since the 1950s, rainfall patterns in India have shown a reduction in the number of rainy days, in rainfall early and late in the season, and in the number of days with low and moderate rainfall, but an increase in the frequency and magnitude of extreme rainfall events (UNEP/WMO, 2011).

**Global climate change is also likely significantly altering monsoon precipitation, causing large shifts in the timing and location of rainfall,** causing major impacts on agriculture (Krishnan et al., 2019). The impacts of global CO<sub>2</sub> emissions thus have acutely felt effects in this region. Nepal, for example, expects to see fewer rainy days, but more days with extreme precipitation in the future (MoFE, 2019). Changing monsoon patterns mean that agriculture and drinking water supply in some places will suffer as a result of water shortages, while other places will suffer from too much water bringing floods and landslides. Just four large flood events in rivers downstream between 2000 and 2013

together killed more than 10,000 people and displaced 50 million (Prabhakar et al., 2018). While precipitation forecasts are more uncertain than temperature forecasts, total summer precipitation will likely increase in the Ganges, upper Salween and upper Mekong Basins, but not in the Indus and Brahmaputra Basins; total winter precipitation on the other hand, will likely increase in the upper Salween and upper Mekong Basins (Shrestha et al., 2015).

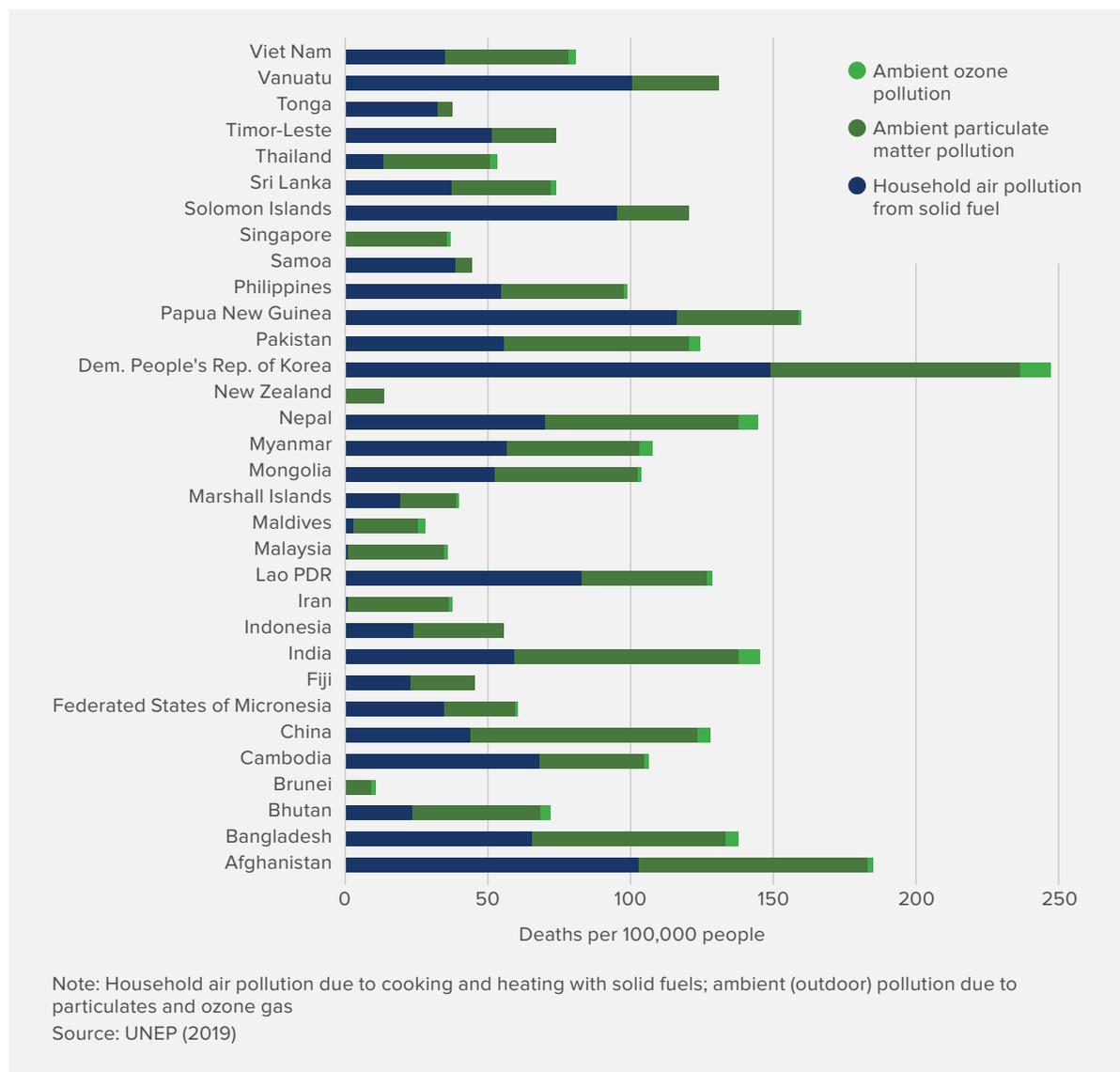
**The regional climate is changing in other ways too.** During the past two decades, the IGP have seen an increase in persistent winter fog events tied to increased air pollution and changing agricultural practices (Saikawa et al., 2019; Syed et al., 2012). Stretching over hundreds of kilometres and lasting for weeks, these fog events affect the daily lives of hundreds of millions of people, with a particularly large impact on the lives and livelihoods of the poorest as well as on air, rail and road transport (Ganguly et al., 2006; Gautam et al., 2007; Saikawa et al., 2019; Syed et al., 2012; UNEP, 2019). Recent projections expect increasingly severe summer heat waves in the IGP, again with impacts on the health and well-being of hundreds of millions of people (Krishnan et al., 2019; Prabhakar et al., 2018).

**“High Mountain Asia has some of the worst air pollution in the world, and is very sensitive to changes in precipitation. Addressing all of its issues requires ambitious and coordinated mitigation action”**

<sup>20</sup> By providing a larger number of surfaces onto which water droplets condense, pollution initially spreads the available water in a cloud among a larger number of smaller droplets too small to rain out, thereby delaying rainfall. However, as the cloud collects more water and the larger number of droplets grows big enough to rain out, the delayed rainfall will become much heavier (Rosenfeld et al., 2008).

<sup>21</sup> And they take place at scales ranging from individual cloud droplets to entire mountain ranges.

**Figure 9:** Annual deaths per 100,000 people due to household and outdoor air pollution, 2016



While the melting Third Pole is very visible, with large downstream consequences, the impacts of other anthropogenic changes to the atmosphere might arguably lead to even more widespread human suffering. The same set of human activities, causing emissions of specific gases and particulates drive both the melting of the Third Pole and these other changes. The interconnected problems and solutions call for coordinated policies, incentives, and actions for effective mitigation (UNEP, 2019). **The Third Pole’s loss of snow and ice is not just a symptom of larger problems, but can also serve as a unifying symbol to address them.**

**“Pollutants that have a climate impact are contributing to melting the Third Pole. Luckily, addressing many of the same combustion sources provides climate, air quality and health co-benefits”**

## RESPONSE TWO: MITIGATION, WITH CO-BENEFITS

Figure 7 illustrated the inter-connections between processes that change the Third Pole cryosphere and processes that drive air pollution and monsoon changes. The individual problems cannot be addressed in isolation; they all require changes in the drivers on the left side of the figure.

### REQUIRED CHANGES

**While some amount of climate change, and some loss of High Mountain Asia's cryosphere, is unavoidable and needs adapting to, keeping these changes within limits is critically important.** The Paris Agreement focuses on keeping global temperature increase 'well below' 2°C while making an effort to keep it below 1.5°C. The special report on the impacts of global warming of 1.5°C by the IPCC (2018), however, emphasizes the huge difference in climate impacts between a world with temperature stabilized at 1.5 versus 2.0°C above pre-industrial levels. This has driven the global discourse towards stabilizing the climate at 1.5°C by achieving **net zero CO2 emissions** in the coming decades. This would entail investment in a wide variety of solutions, some currently cost-effective, some less, in sectors ranging from buildings and cities, to energy, food, land use, materials, and transport (Hawken, 2017). One important priority is ending fossil fuel subsidies; according to an International Monetary Fund estimate, in 2015 the fossil fuel industry received \$5.3 trillion in direct and indirect subsidies, equivalent to 6.5 percent of global GDP (Hawken, 2017).

**The protection of the snowfields and glaciers of High Mountain Asia, along with the region's air quality and monsoon system, requires concerted global action well beyond the Paris Agreement in order to stabilize Earth's climate at a lower temperature.** This requires going far beyond gradually phasing out CO2 emissions, and making a concerted effort to reach a peak as soon as possible and then draw down<sup>22</sup> atmospheric CO2 concentrations. Since impacts of CO2 emissions do not depend on the source, and emissions take place across many different sources and sectors, one should start with feasible sources that provide the biggest potential

for quick and easy reductions. Project Drawdown, a California-based organization, has worked with hundreds of experts to quantify the impacts and costs of the most promising such solutions (Hawken, 2017). The top ten include removing HFCs from refrigeration, investing in wind and solar power, reducing food waste and switching away from meat, letting trees grow on pastures, and reducing population growth through education of girls and improved access to family planning.

**Due to CO2's long lifetime, it will take far too long to stabilize global temperatures through CO2 mitigation alone. This is where mitigating short-lived climate pollutants comes in.** By scaling up existing technologies, (UNEP/WMO, 2011), reduction of SLCPs can provide a 0.5°C of avoided warming while achieving significant societal co-benefits (Shindell et al., 2017; UNEP, 2011). In fact, as illustrated in Figure 10, without reducing SLCPs it will be almost impossible to contain global temperatures within 1.5°C by the year 2100 (IPCC, 2018). Mitigating SLCPs alone also makes no sense, since warming driven by CO2 would continue and at some point overwhelm the one time temperature reduction of 0.5°C from SLCP mitigation (Shindell et al., 2017). Effective mitigation will require a set of integrated solutions based on an analysis of all the impacts.

**The interrelated nature of many of the problems and solutions makes it easy to address multiple issues in an integrated way through politically expedient framing.** For example, the assessment report *Air Pollution in Asia and the Pacific: Science-Based Solutions*, published jointly by Climate and Clean Air Coalition (CCAC), United Nations Environment Programme (UNEP) and Asia Pacific Clean Air Part-

<sup>22</sup> *Project Drawdown* by Hawken (2017) looks for solutions beyond reducing emissions to finding ways to reduce atmospheric CO2 concentrations.

nership (2019),<sup>23</sup> rested on the premise that the most effective way to motivate climate change mitigation in Asia would focus on reducing the region’s fine particulate pollution – a widely agreed problem – which would also yield a positive impact on climate. Through a sophisticated modelling approach, the as-

essment identifies the 25 most promising measures that, if implemented in Asia and the Pacific, would both significantly clean up the region’s air pollution, and achieve 0.3°C of avoided global warming by mid-century (Box 2).

**Box 2: 25 most important clean air measures**

These 25 clean air measures can positively impact climate change, human health, crop yields, socio-economic development, and contribute to achieving the Sustainable Development Goals. Implementing these

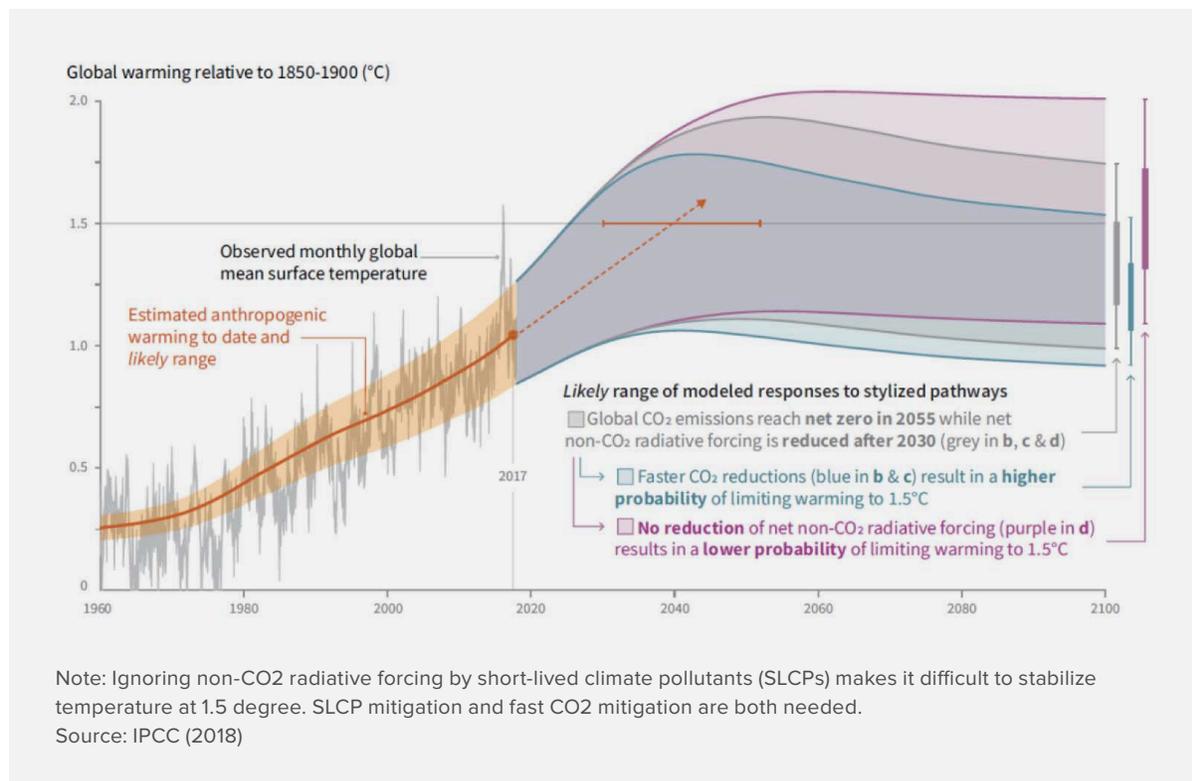
measures in Asia and the Pacific could help preserve the Third Pole while also helping 1 billion people breathe cleaner air by 2030 and reducing global warming by a third of a degree Celsius by 2050.

- |                                                                   |                                                                    |
|-------------------------------------------------------------------|--------------------------------------------------------------------|
| 1 Strengthen emission standards for road vehicles                 | 14 Strictly enforce bans on household waste burning                |
| 2 Regularly inspect and maintain vehicles                         | 15 Provide incentives for improved energy efficiency in households |
| 3 Mainstream electric vehicles                                    | 16 Increase renewable electricity generation                       |
| 4 Provide better mobility options                                 | 17 Improve energy efficiency for industry                          |
| 5 Control dust from construction and roads                        | 18 Recover coal mining gas                                         |
| 6 Reduce emissions from international shipping                    | 19 Improve livestock manure management                             |
| 7 Improve post-combustion control                                 | 20 Strengthen management of nitrogen fertilizer application        |
| 8 Strengthen industrial process emissions standards               | 21 Better management of agricultural crop residues                 |
| 9 Introduce efficient brick kilns technology                      | 22 Prevent forest and peatland fires                               |
| 10 Control volatile organic compounds from oil and gas production | 23 Promote more efficient rice production practices                |
| 11 Improve solvent use and refinery controls                      | 24 Stop biogas leakage from wastewater treatment                   |
| 12 Use environmentally-friendly refrigerants                      | 25 Improve solid waste management                                  |

Source: CCAC, UNEP and Asia Pacific Clean Air Partnership (2019)

<sup>23</sup> Arnico Panday was a lead author on this report.

**Figure 10:** Probable global average temperature pathways under three different scenarios



**The 25 most important measures to clean up Asia-Pacific’s air quality fall into three categories. The first category is called “Regional Application of Conventional Measures.”** These comprise measures that normally form centrepieces in air quality management, but have not seen broad deployment around the region. They include industrial emission control through end-of-pipe devices and emissions standards; emission standards for vehicles, along with vehicular inspection and maintenance; and dust control on construction sites and roads. **The second category of measures, “Next-stage Air Quality Measures” remain uncommon in Asia and the Pacific.** These include banning open burning of agricultural crop residue and residential waste, preventing forest and peatland fires, livestock manure management (to reduce methane emissions), better management of fertilizer application, improved brick kilns, reducing emissions from international shipping, and reducing leaks and emissions from refineries and paint production. **The third category consists of measures that contribute to economic and human development priority goals through air quality benefits.** The first of these involves switching households away from solid fuels, to cook and heat with electricity or gas. In fact, one study identified switch-

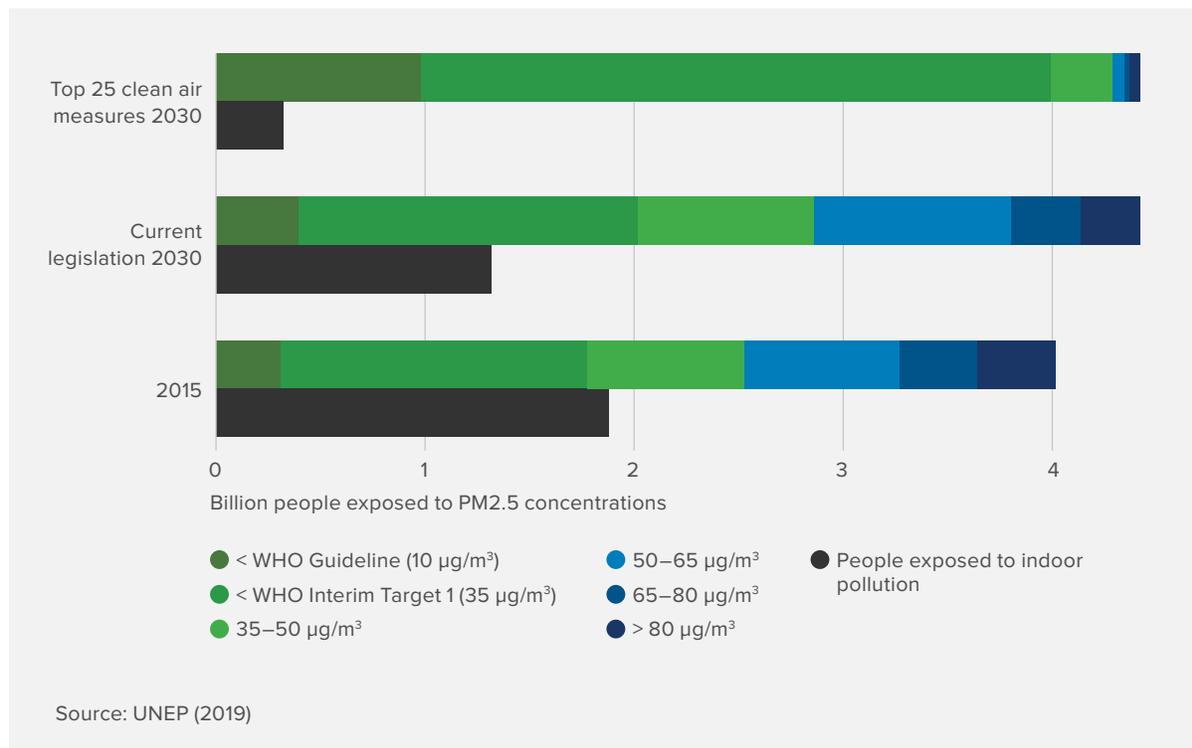
ing to clean cooking as the most important measure to reduce black carbon reaching the cryosphere (The World Bank, 2013). Other solutions include shifting electricity production from thermal to solar, wind and hydropower; giving households incentives for more energy-efficient appliances and for installing rooftop solar panels; introducing energy efficiency standards for industries; promoting electric vehicles; improving public transport; improving solid waste management; several measures to reduce methane emissions including intermittent aeration of rice fields, two-stage water treatment and biogas recovery, pre-mining recovery of coal mine gas, stopping routine flaring and reducing leaks in oil and gas production; as well as full compliance with the Kigali Amendment to replace HFCs in refrigeration. A number of these measures are identical to ones listed by Project Drawdown to reduce CO<sub>2</sub> globally, underscoring the interconnectedness of the problems and solutions.

Figure 11 illustrates the impact of implementing these 25 measures on levels of PM<sub>2.5</sub> exposure. While implementation of current legislation already ensures that the number exposed to high levels of air pollution will not grow by 2030, implementation of the 25 measures will

greatly decrease the exposure levels faced by these four billion people. Figure 12 illustrates this data in a different form, looking at the impact of the measures on average PM2.5 exposure faced by residents of Asia-

Pacific. The implementation of conventional, next-stage, and development-priority measures will bring the average annual PM2.5 to within 20 micrograms per cubic meter – just double the WHO guideline!

**Figure 11:** Number of people exposed to different levels of pollution in 2015, in 2030 under current legislation, and if the 25 measures are implemented

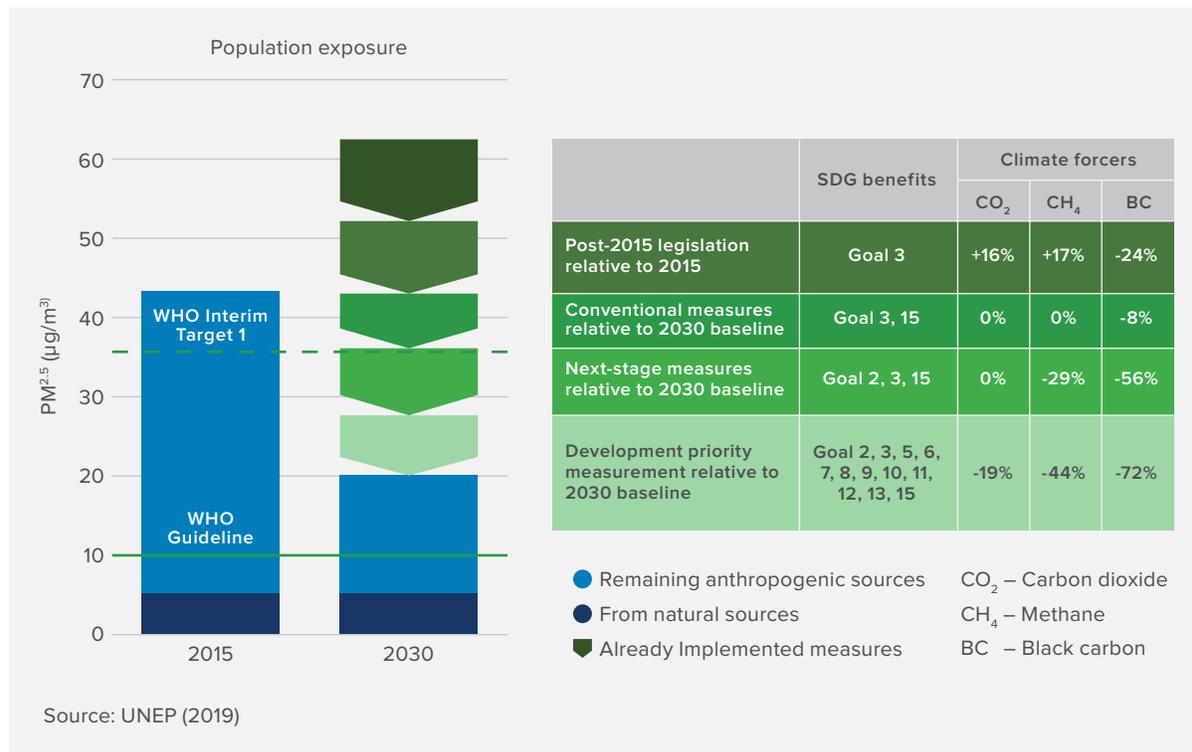


**The countries of Asia and the Pacific span the ranks from among the smallest to the largest.** Global CO2 emissions are dominated by China, the United States, the European Union and India; significant emission reduction in those countries will make a big difference globally, while the current net-zero conditions in Bhutan have virtually no impact on the global environment. **Smaller countries, states, and cities, however, have the opportunity to become more ambitious more quickly than larger countries, demonstrating proofs-of-concept before their wider introduction in larger countries.** A case in point: the work carried out by the team that focused on the 100 or so brick kilns in the Kathmandu Valley, Nepal, after the 2015 earthquake. They introduced design changes that improved combustion and thermal efficiency, resulting in significant reductions in air pollution along with savings for the kiln owners (Nepal et al., 2019). The improved kilns attracted visitors from the region, leading to policy changes that required the clean-up of 20,000 kilns in Punjab Province, Pakistan, and catalysed the formation of the South Asian

Federation of Brick Kiln Associations. To give another example, small countries with a high proportion of clean hydropower, such as Bhutan and Nepal, should find it easier to switch to all-electric vehicle fleets than some of the larger countries.

**“The world must shift away from fossil fuel use in energy, transport, and other sectors, while changing diets and agricultural practices”**

**Figure 12:** Clean-air policy effects on emission reductions, SDGs, and cumulative CO2 in Asia and the Pacific, 2015 v. 2030 (population-weighted PM2.5)



## NECESSARY ACTIONS

Achieving effective and lasting actions that limit the damage caused by climate change in High Mountain Asia requires **attention to several priorities:**

- (1) While the broader picture of interrelated processes has started to emerge, specific decisions require new data and more research. The region is one of the most complex in the world, and only detailed environmental monitoring and research will detect vulnerabilities and future challenges. This requires **allocation of sufficient funds to environmental monitoring and research.**
- (2) Many countries of the region have notoriously low levels of communication between academics and decision-makers. **These countries should develop platforms that allow effective communication of physical as well as social science results relevant to policymaking,** along with questions from policymakers that require academic input.
- (3) As the complex interplay between human activities, drivers of environmental change, and impacts cross a variety of sectors, **governments will need to strengthen cross-sectoral institutions** that can reach across typically siloed ministry structures.
- (4) Issues and problems cross borders, both between subnational jurisdictions and between countries. **This calls for developing effective communication platforms to ensure cross-border sharing of data, information, knowledge and experiences.**
- (5) Multinational and intergovernmental institutions and fora need strengthening, along with a mandate to develop regional frameworks and targets, agreed upon by the region's governments, to protect the Third Pole. This can become a unifying goal that takes attention away from smaller contentions in the region such as border disputes.

- (6) Globally, the loss of snow and ice from High Mountain Asia's peaks needs to be seen not as a distant problem, but as a symbol and a symptom of a global system imbalance that calls for urgent action.

UNDP's status and presence in the countries throughout the region give it an opportunity to engage with actors at different levels and to shape the discourse over the coming decade. **Keeping the Third Pole snow and ice covered, the skies blue, the lungs healthy and rainfall regular, requires taking responsibility at all levels, from individuals to firms, local and national governments and global organizations.** This is a message that UNDP can emphasize.

Regardless of their socio-economic status, **individuals have a responsibility to inform themselves and to make appropriate consumer choices.** This includes, for example, giving priority to buying clean cookstoves over flashy gadgets and adjusting to a more plant-based diet. Wealthier individuals have the responsibility to choose sustainable ways to travel, to limit fossil-fuel powered road and air travel, to reduce the use of plastics, to change their diet, and to pay attention to the source of their material purchases. Local and municipal governments have a responsibility to discourage harmful activities within their jurisdictions and to build healthy sustainable cities. They will need to provide disincentives for burning crop residue and garbage, and create walkable cities with convenient public transport. They may also be able to restrict entry of vehicles and materials that do not meet certain standards. National governments have the responsibility to adopt taxes and rules that promote clean transport and energy, that promote investments by firms in appropriate areas. They also have the responsibility to treat climate change as the emergency that it is, and to allocate sufficient resources for both adaptation and mitigation.

**Regional and global organizations**, from the HKH-based ICIMOD, to the Climate and Clean Air Coalition (CCAC), as well as various UN bodies need to use the

weight of international mandate to push for cross-border coordination, cooperation, and sharing. At times, they may need to grow louder about calling their member countries to action.

**UNDP itself can play an important role both globally and within member countries.** First, it can set an example through its country offices, replacing its vehicle fleets with only electric vehicles and powering its offices through renewable energy. Second, it can launch an educational campaign on what responsible leadership means for the next decade, providing guidelines to politicians but also raising the expectations of voters. Finally, it can seek to enter into partnerships with big technology firms, getting them to pledge to use only renewable energy at their server farms and to use their platforms to educate the public and to provide complete lifecycle analyses and environmental impact information for all of the products they sell.

In concluding its review of a broad range of challenges facing High Mountain Asia, *The Hindu Kush Himalaya Assessment* notes that, while significant knowledge gaps remain about the region, "we know enough to take action" (Wester et al., 2019). As we look at the decade ahead, it will be critical for individuals, governments, businesses and organizations to give priority to stabilizing the global climate, thereby also protecting the Third Pole and the lives and livelihoods of the people living downstream from it.

**“Everyone has a role to play in the major changes needed in the coming decade to prevent further pollution and climate change, from individuals to governments to UNDP, in order to preserve the Third Pole and its people”**

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