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The Montreal Protocol and the Sustainable Development Goals

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In the two decades since former UN Secretary General Kofi Annan described the Montreal Protocol on Substances that Deplete the Ozone Layer as "... perhaps the single most successful international environmental agreement to date" its success in protecting the environment has become even more clear[1]. Yet the benefits of the treaty are measurable by more than reduced emissions of ozone-depleting substances (ODS) and the recovery of the Antarctic stratospheric ozone layer[2]. They are also evident in protecting the health and well-being of people around the world, and the environment far beyond the stratospheric ozone layer.

One way of exploring these wider successes of the Montreal Protocol is through the lens of the UN Sustainable Development Goals (SDGs[3]). The Protocol contributes to at least twelve of the seventeen SDGs (Table 1). At first sight, it may seem odd to link the Montreal Protocol, signed in 1987, with the SDGs that were only agreed in 2015[3]. In fact, the additional benefits of the Montreal Protocol and its link to development have been explicit from the very start of global ozone protection policy. The first page of the Vienna Convention for the Protection of the Ozone Layer, written in 1985, frames its purpose as follows:

"The Parties to this Convention... Aware of the potentially harmful impact on human health and the environment through modification of the ozone layer, ... taking into account the circumstances and particular requirements of developing countries [and] ....determined to protect human health and the environment against adverse effects resulting from modifications of the ozone layer."[4]

What has become clear in the last thirty years is that the Vienna Convention and Montreal Protocol have delivered even more benefits to human health and the environment than were originally envisaged, and by a wider range of mechanisms (Table 1).

1 UNEP, *Synthesis of the 2014 Reports of the Scientific, Environmental Effects, and Technology & Economic Assessment Panels of the Montreal Protocol* 2015, Nairobi: United Nations Environment Programme.

2 WMO, Scientific Assessment of Ozone Depletion: 2018, Global Ozone Research and Monitoring Project–Report No. 58, 2018, World Meteorological Organization: Geneva, Switzerland.

3 https://www.un.org/sustainabledevelopment/development-agenda/

4 https://ozone.unep.org/sites/default/files/2019-04/VC-Text%20 2016-English_0.pdf.

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Multiple pathways to supporting the SDGs

The most direct contributions of the Montreal Protocol to achieving the SDGs comes from its proven success in protecting the ozone layer and protecting the climate[2]. These benefits are often described by reference to the 'world avoided', a world without the successful implementation of the Montreal Protocol and so with run-away ozone depletion leading to increases in UV radiation beyond anything experienced in human history[1].

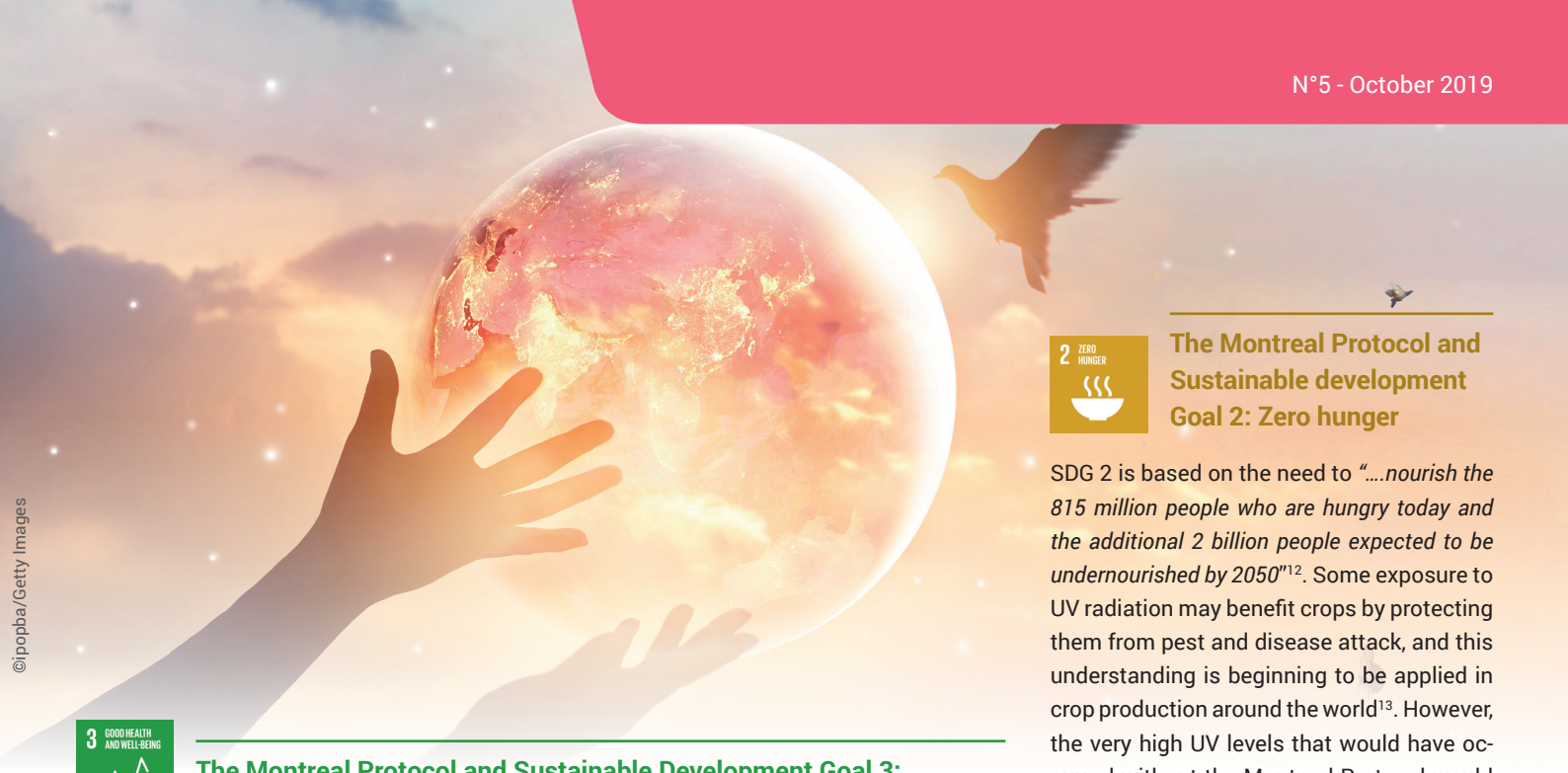
TABLE 1.
The SDGs[3] and the different mechanisms by which the Montreal Protocol is contributing to their delivery

	Direct contribution based on ozone protection	Direct contribution based on climate protection	Direct contribution based on the Multilateral Fund	Indirect contribution based on innovative technologies	Indirect contribution based on new scientific knowledge
 **GOAL 2** Zero Hunger	✓	✓		✓	✓
 **GOAL 3** Good Health and Well-being	✓	✓		✓	✓
 **GOAL 6** Clean Water and Sanitation					✓
 **GOAL 7** Affordable and Clean Energy			✓	✓	
 **GOAL 8** Decent Work and Economic Growth			✓	✓	
 **GOAL 9** Industry, Innovation and Infrastructure			✓	✓	✓
 **GOAL 11** Sustainable Cities and Communities			✓	✓	✓
 **GOAL 12** Responsible Consumption and Production			✓	✓	
 **GOAL 13** Climate Action		✓	✓	✓	✓
 **GOAL 14** Life Below Water	✓	✓			✓
 **GOAL 15** Life on Land	✓	✓			✓
 **GOAL 17** Partnerships to achieve the Goal			✓	✓	✓

Based on the 2018 assessment reports of the Environmental Effects Assessment Panel[5] and Technology and Economics Assessment Panel[6]. Direct contributions are those that are based on the success of the Montreal Protocol in controlling ozone depleting substances and so protecting the ozone layer (so preventing large increases in UV radiation) and the climate. Another direct contribution comes from the establishment of the Multilateral Fund for the Implementation of the Montreal Protocol that has stimulated international cooperation relevant to many SDGs. Indirect contributions are those based on the stimulation of technological innovation and scientific research that have also supported progress towards multiple SDGs.

In addition to 'direct' benefits from protecting the ozone layer, the Protocol has also driven technological innovations that have made their own contributions to delivering the SDGs beyond those delivered directly by protecting the ozone layer (Table 1). The world avoided would have been a world in which vital innovations across multiple technologies, from air conditioning and refrigeration to crop protection, might never have happened[6]. These technological advances place the Montreal Protocol at the heart of SDG9 (Industry, Innovation and Infrastructure).

A less tangible but important impact of the Montreal Protocol has been the stimulation of scientific research in to how UV radiation affects people, other organisms, ecosystems and chemical processes[5]. As outlined below, this research has led to new understanding that has contributed to progress towards multiple SDGs.



The Montreal Protocol and Sustainable Development Goal 3: Good health and well-being

The links between protecting the ozone layer and protecting human health are clear[7]. There is no doubt that without effective implementation of the Montreal Protocol increases in UV radiation due to uncontrolled stratospheric ozone depletion would have had major effects on human health[1]. Models of the health effects of the world-avoided in the United States alone suggest that the Protocol and its amendments will have prevented hundreds of millions cases of skin cancer and tens of millions of cases of cataract by the end of this century[1]. Indirectly, the Montreal Protocol has greatly increased public awareness of the link between skin cancer and exposure to UV radiation, and so has contributed to many successful public health campaigns encouraging 'sun safe' behaviour[7].

As well as these well –known effects on skin cancers and eye disease, it is increasingly clear that increased exposure to solar UV radiation can reduce the efficacy of vaccination, which is widely recognized as *'…. one of the world's most successful and cost-effective health interventions'*[8]. Increases in UV radiation due to even moderate stratospheric ozone depletion could have compromised SDG3 by reducing the efficiency of vaccination against major global diseases, such as tuberculosis, measles and influenza.

Improved understanding of the role of UV radiation in destroying disease-causing microbes[9, 10] has contributed to 'solar sterilisation', a low-cost approach to delivering clean drinking water, and so to delivering SDG 6 (Clean Water and Sanitation) as well as SDG3 and SDG14.

The notable achievements of the Montreal Protocol in protecting the climate[1], which will be extended through the implementation of the Kigali Amendment (see below: SDG 13), will also protect human health. Global heating, and especially the resulting increases in the frequency and severity of extreme events, such as heat waves, droughts and floods, are expected to lead to a range of direct and indirect damaging effects on human health[11].

The Montreal Protocol and Sustainable development Goal 2: Zero hunger

SDG 2 is based on the need to *"….nourish the 815 million people who are hungry today and the additional 2 billion people expected to be undernourished by 2050"*[12]. Some exposure to UV radiation may benefit crops by protecting them from pest and disease attack, and this understanding is beginning to be applied in crop production around the world[13]. However, the very high UV levels that would have occurred without the Montreal Protocol would have damaged many crops. Uncontrolled increases in UV radiation would also have damaged aquatic ecosystems that are the basis of the commercial fisheries, a vital source of food around the world[9]. It remains hard to quantify the severity of these losses in food production in the world avoided. However, for crops there is evidence that even a 10% reduction in stratospheric ozone, much less than predicted in the world avoided, might have reduced plant production by around 6%[13]. The phase-out of methyl bromide under the Montreal Protocol[6] has stimulated new approaches to agricultural production systems, including pest and disease control, fertilization and irrigation practices and others. New ozone-safe methods of pest and disease control in crops and stored food contribute to sustainable approaches to reducing food waste, which currently results in the loss of about 30% of food produced every year[14]. The role of the Montreal Protocol in enabling access to high-energy efficient, ozone-safe cooling systems also contributes to reducing food waste[6], and so to delivering SDG 2.

5 EEAP, Environmental Effects Assessment Panel Environmental Effects and interactions of Stratospheric Ozone Depletion, UV radiation and climate change: 2018 Assessment Report, J.F. Bornman and N.D. Paul, Editors., United Nations Environment Programme: Nairobi.

6 TEAP, Technology and Economic Assessment Panel 2018 Assessment Report, United Nations Environment Programme: Nairobi.

7 Lucas, R.M., *et al., Human health in relation to exposure to solar ultraviolet radiation under changing stratospheric ozone and climate, in Environmental Effects Assessment Panel: Environmental Effects and interactions of Stratospheric Ozone Depletion, UV radiation and climate change: 2018 Assessment Report*, J.F. Bornman and N.D. Paul, Editors. 2018, United Nations Environment Programme: Nairobi. p. 79-149.

8 https://sustainabledevelopment.un.org/sdg3#.

9 Williamson, C.E., *et al., The interactive effects of ozone depletion, UV radiation, and climate change on aquatic ecosystems, in Environmental Effects Assessment Panel: Environmental Effects and interactions of Stratospheric Ozone Depletion, UV radiation and climate change: 2018 Assessment Report*, J.F. Bornman and N.D. Paul, Editors. 2018, United Nations Environment Programme: Nairobi. p. 201-242.

10 Sulzberger, B., *et al., Solar UV radiation in a changing world: Roles of cryosphere-land-water-atmosphere interfaces in global biogeochemical cycles, in Environmental Effects Assessment Panel: Environmental Effects and interactions of Stratospheric Ozone Depletion, UV radiation and climate change: 2018 Assessment Report*, J.F. Bornman and N.D. Paul, Editors. 2018, United Nations Environment Programme: Nairobi. p. 243-283.

11 Smith, K.R., *et al., Human health: impacts, adaptation, and co-benefits.* . Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change 2014, Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

12 https://www.un.org/sustainabledevelopment/hunger/.

13 Bornman, J.F., *et al., Linkages between stratospheric ozone, UV radiation and climate change and their implications for terrestrial ecosystems, in Environmental Effects Assessment Panel: Environmental Effects and interactions of Stratospheric Ozone Depletion, UV radiation and climate change: 2018 Assessment Report*, J.F. Bornman and N.D. Paul, Editors. 2018, United Nations Environment Programme: Nairobi. p. 151-199.

14 http://www.fao.org/policy-support/policy-themes/food-loss-food-waste/en/.

15 Andrady, A.L., *et al., Interactive effects of solar UV radiation and climate change on material damage, in Environmental Effects Assessment Panel: Environmental Effects and interactions of Stratospheric Ozone Depletion, UV radiation and climate change: 2018 Assessment Report*, J.F. Bornman and N.D. Paul, Editors. 2018, United Nations Environment Programme: Nairobi. p. 329-359.

16 UNEP, *The Montreal Protocol and the Green Economy: Assessing the contributions and co-benefits of a Multilateral Environmental Agreement* 2012, Nairobi: United Nations Environment Programme.

SUSTAINABLE DEVELOPMENT GOALS

The Montreal Protocol and Sustainable Development Goal 7 (Affordable and clean energy), Sustainable Development Goal 8 (Decent Work and Economic Growth), Sustainable Development Goal 9 (Industry, Innovation and Infrastructure), Sustainable Development Goal 11 (Sustainable Cities and Communities) and Sustainable Development Goal 12 (Responsible Consumption and Production)

The contributions of the Montreal Protocol for these five interlinked socio-economic SDGs are all fundamentally related to technological advances stimulated by ozone protection but ultimately delivering much wider benefits to Industry, Innovation and Infrastructure (SDG9). These include new knowledge of how UV affects the durability of building materials[15], but the greatest contribution of the Protocol comes from the profound changes in refrigeration and air conditioning[6]. Changes were driven primarily by the need to phase-out ozone depleting substances, and so a prime example of policy and technology working together to support Responsible Consumption and Production (SDG 12). Furthermore, the need to develop new ozone-safe systems has also allowed manufacturers to improve the energy efficiency of their products, allowing energy resources to be used most efficiently[6]. The Kigali Amendment to phase out high global warming hydrofluorocarbons (HFCs) will extend this 'win-win'. HFCs replace ozone-damaging substances, like chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), as coolants in refrigeration and air conditioning, but while HFCs are safe for the ozone layer, some are very potent greenhouse gases[2]. The Kigali Amendment is stimulating not just a shift towards using lower global warming coolants, it is also allowing manufacturers and users to move to refrigeration and air conditioning systems that will further improve energy efficiency[6]. As a result, although the Protocol may not have contributed to new approaches to energy generation, its implementation has contributed to efficient energy use[6]. This contribution to SDG7 also helps deliver SDG11 (Sustainable Cities and Communities) by promoting more sustainable use of air conditioning[6]. As pointed out by the 'Montreal Protocol and the Green Economy report'[16], the socio-economic benefits of the Protocol include a shift to jobs requiring a more highly-trained workforce, improved health and safety, and driving the shift towards a greener economy, all of which are direct contributions to SDG8.

The Montreal Protocol and Sustainable Development Goal 13: Climate action

By phasing-out ozone depleting substances that are also powerful greenhouse gases, the Montreal Protocol has already made a major contribution to protecting the climate[1, 2]. Looking to the future, the phase-down of high global warming HFCs via the Kigali Amendment, (see above), is expected to reduce global heating by another 0.4°C[2]. By protecting the climate, the Montreal Protocol contributes not only to SDG13 but also many other SDGs, as noted above.

The Montreal Protocol and Sustainable Development Goals 14 (Life below Water) and 15 (Life on Land)

Just as excess UV radiation can damage human health it is clear that it can have multiple effects on other organisms[5]. By preventing the very large increases in UV radiation that would have occurred without effective protection of stratospheric ozone, the successful implementation of the Montreal Protocol has protected life below water (SDG14) and Life on Land (SDG15). Quantification of the scale of that damage remains challenging since, as yet, there are no 'world avoided' models for ecological effects. The success of the Protocol in protecting climate (SDG 13, above) will also have directly protected terrestrial and aquatic ecosystems from the damaging effects of climate change[9,13]. Indirectly, research stimulated by the Montreal Protocol has led to much improved understanding the ecological effects of UV radiation[9, 10, 13]. One example is the recognition that UV radiation provides an invaluable 'ecosystem service' by controlling populations of disease-causing organisms in and breaking-down many pollutants aquatic ecosystems[9, 10]. We also know that UV can alter the balance between native and introduced plants in terrestrial ecosystems[13]. This new understanding informs SDG 14 and SDG 15 as ecosystems world-wide face the multiple challenges of changes in climate and land-use, pollution etc.

The Montreal Protocol and Sustainable Development Goal 17: Partnership for the Goals

Partnership is at the heart of the Montreal Protocol, based on essential principles of commitment, consensus and assistance[1]. The countries of the developed world assist developing countries to meet their commitments under the Protocol via the Multilateral Fund for the Implementation of the Montreal Protocol. The Multilateral Fund has approved incremental costs nearly 3.5 billion USD for projects that include industrial conversion, training and capacity building[1]. Many of the Protocol's contributions to delivering the SDGs described above are founded on the parties working in partnership through the Multilateral Fund[16].

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