**Technical assessment for**

**Peatland Restoration**

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**Prepared by:**

**Jimena Alvarez, Research Fellow**

**Mamta Mehra, Senior Fellow**

**Eric Toensmeier, Senior Fellow**



27 GATE 5 RD., SAUSALITO, CA 94965 [info@drawdown.org](mailto:info@drawdown.org) [www.drawdown.org](http://www.drawdown.org)

Table of Contents

[List of Figures 4](#_Toc9172271)

[List of Tables 4](#_Toc9172272)

[Acronyms and Symbols Used 5](#_Toc9172273)

[Executive Summary 6](#_Toc9172274)

[1. Literature Review 7](#_Toc9172275)

[1.1. State of the Practice 7](#_Toc9172276)

[1.2. Adoption Path 13](#_Toc9172277)

[1.2.1 Current Adoption 13](#_Toc9172278)

[1.2.2 Trends to Accelerate Adoption 13](#_Toc9172279)

[1.2.3 Barriers to Adoption 14](#_Toc9172280)

[1.2.4 Adoption Potential 14](#_Toc9172281)

[1.3 Advantages and disadvantages of SOLUTION 15](#_Toc9172282)

[1.3.1 Similar Solutions 15](#_Toc9172283)

[1.3.2 Arguments for Adoption 15](#_Toc9172284)

[1.3.3 Additional Benefits and Burdens 15](#_Toc9172285)

[2 Methodology 18](#_Toc9172286)

[2.1 Introduction 18](#_Toc9172287)

[2.2 Data Sources 18](#_Toc9172288)

[2.3 Total Available Land 18](#_Toc9172289)

[2.4 Adoption Scenarios 19](#_Toc9172290)

[2.4.1 Reference Case / Current Adoption 20](#_Toc9172291)

[Project Drawdown Scenarios 21](#_Toc9172292)

[2.5 Inputs 21](#_Toc9172293)

[2.5.1 Climate Inputs 21](#_Toc9172294)

[2.5.2 Financial Inputs 23](#_Toc9172295)

[2.5.3 Other Inputs 23](#_Toc9172296)

[2.6 Assumptions 23](#_Toc9172297)

[2.7 Integration 24](#_Toc9172298)

[2.8 Limitations/Further Development 25](#_Toc9172299)

[3 Results 26](#_Toc9172300)

[3.2 Adoption 26](#_Toc9172301)

[3.3 Climate Impacts 27](#_Toc9172302)

[3.4 Financial Impacts 29](#_Toc9172303)

[4 Discussion 30](#_Toc9172304)

[4.1 Limitations 30](#_Toc9172305)

[4.2 Benchmarks 30](#_Toc9172306)

[5 References 31](#_Toc9172307)

[6 Glossary 35](#_Toc9172308)

# List of Figures

[Figure 3.1 World Annual Adoption 2020-2050 27](#_Toc9172309)

[Figure 3.2 World AnnualGreenhouse Gas Emissions Reduction 28](#_Toc9172310)

# List of Tables

[Table 1.1 Food Production Solutions Comparison: On-Farm Impacts 16](#_Toc9172311)

[Table 1.2 Food Production Solutions Comparison: On-Farm Impacts Social and Ecological Impacts 16](#_Toc9172312)

[Table 2.1 Climate Inputs 22](#_Toc9172313)

[Table 3.1 World Adoption of the Solution 26](#_Toc9172314)

[Table 3.2 Climate Impacts 28](#_Toc9172315)

[Table 3.3 Impacts on Atmospheric Concentrations of CO2-eq 29](#_Toc9172316)

[Table 4.1 Benchmarks 30](#_Toc9172317)

# Acronyms and Symbols Used

# Executive Summary

Project Drawdown defines *peatland* protection as the re- establishment of“*self-regulatory mechanisms that will lead back to functional peat accumulating ecosystems*” (Quinty and Rochefort, 2003. It is assumed that *peatland restoration* primarily happens at the government level.

Peatlands are a hugely important stock of soil organic carbon. Despite covering less than 3 percent of the global land area, they hold 30 percent of all soil carbon, amounting to at least 500 gigatons – twice the carbon stock of all forest biomass. Unlike most terrestrial ecosystems, peatlands do not reach saturation, and continue sequestering carbon in soil organic matter for centuries or millennia.

Peatlands are currently being degraded for agricultural, horticultural, forest, fuel, and infrastructural needs. An estimated 15 percent of the world’s peatlands have been degraded so far, and nearly 50 percent of that degradation is for agricultural land use. Peatland degradation for various land uses is leading to enormous carbon emissions. Currently, peatlands are degrading at the annual rate of 0.4 million hectares per year. Moreover, global peat volume is decreasing at an annual rate of 20 cubic kilometers per year. Peatland degradation results in nearly 3 gigatons of carbon dioxide-equivalent emissions per year, equivalent to more than 10 percent of global fossil fuel emissions. The rate is expected to increase in the future unless land management practices and peatland development plans are changed and reconsidered.

It is extremely important to prevent any further degradation of peatlands as well as to restore drained peatlands given the mitigation benefit of decrease in emissions it provides. Out of a total land area available for the solution of 62 Mha, the current solution adoption (2014) is 0 Mha due to the lack of sources for regional or global restoration areas. Five custom adoption scenarios were developed using national peatland restoration commitments scaled up at the global level for three of them and linear increases up to percentages of TLA (related to these restoration commitments) for the other two. These were then combined to produce the *Plausible, Drawdown* and *Optimum* scenarios.

In the *Plausible* Scenario, 35.16 million hectares come under protection. Climate impact is 12.07 gigatons of carbon dioxide equivalent.

In the *Drawdown* Scenario, 47.04 million hectares come under protection. Climate impact is 16.13 gigatons of carbon dioxide equivalent.

In the *Optimum* Scenario, 58.92 million hectares come under protection. Climate impact is 20.18 gigatons of carbon dioxide equivalent.

Financials are not modeled.

# Literature Review

## State of the Practice

Peatlands cover about 4.23 ×106 km2 area representing 2.84% of the global area (Xu et al., 2018). Despite representing less than 3% of the global land area, peatlands contain at least 550 Gt of carbon (Barthelmes et a., 2015). Peatland is primarily found in freshwater wetlands having an organic soil layer of at least 30 cm, which may extend to 15-20 m depth (Biancalani, Avagyan, & others, 2014; Clymo, Turunen, & Tolonen, 1998; Gorham, 1991; Hans Joosten & Clarke, 2002; Kaat & Silvius, 2006; Strack, 2008; M Strack & Zuback, 2013; Turunen, Tomppo, Tolonen, & Reinikainen, 2002).

Asides from carbon storage peatland ecosystems play crucial roles: “in water catchments as a source of drinking water, regulating water supply and in maintaining healthy rivers and lakes. Peat also provides an archaeological and environmental archive preserving bodies, artefacts and information on past environmental conditions stretching back thousands of years.” (Cris et al., 2014). Despite all these benefits, several drivers like logging, peat conversion to other land uses and extraction for horticultural purposes have resulted in high levels of peatland degradation (Dohong et al., 2017). Despite drained peatlands represent 0.3% land area, the resulting emissions reached almost 6% of global anthropogenic CO2 emissions (Cris et al., 2014). As depicted in figure 1 below, drained peatlands have negative environmental consequences asides from an increase in greenhouse gases emissions, which range from increased carbon loss via water and flood risk, land degradation and increased fire frequency to biodiversity loss (IUCN, 2017). In addition, “Simply abandoning the past drained peatlands presents severe fire risk and further degradation, soil subsidence and erosion. The longer the delay in taking remedial action, the greater the damaging consequences of degraded peatlands and the more costly it becomes to repair.” Cris et al. (2014).

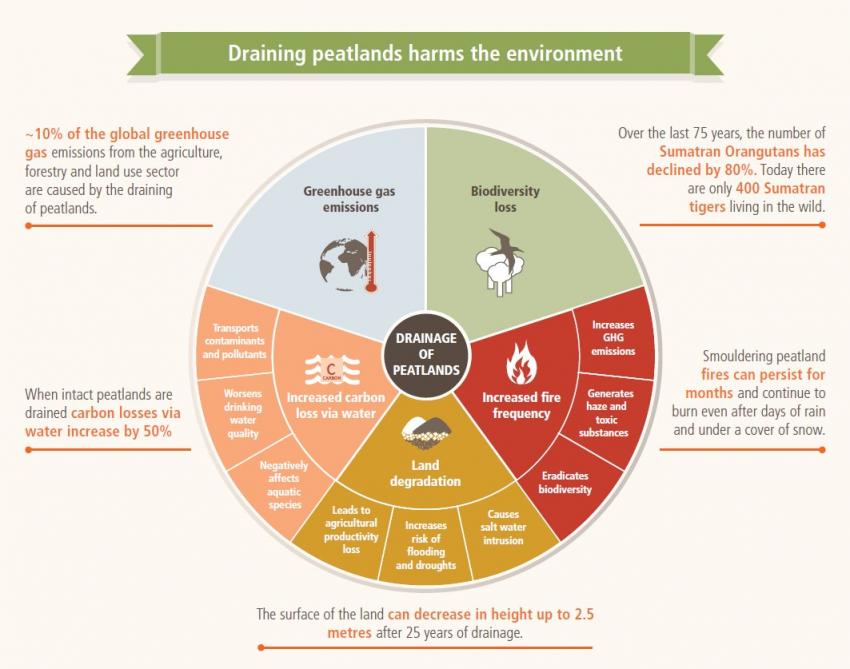


Figure 1:Peatland degradation impacts

*Source:* [*https://www.iucn.org/resources/issues-briefs/peatlands-and-climate-change*](https://www.iucn.org/resources/issues-briefs/peatlands-and-climate-change)

Restoring degraded peatlands is crucial to counterbalance the negative effects described above. It should be noted that “Peatland soils and the habitats and species they support have developed over millennia and while restoration can help recover ecosystem function, it cannot replace the full extent of what has been lost on a site in any meaningful timescale.” (Cris et al., 2014).

We define peatland restoration as the re- establishment of“*self-regulatory mechanisms that will lead back to functional peat accumulating ecosystems*” (Quinty and Rochefort, 2003). Schumann and Joosten (2008) define restoration as “the process of bringing something back to what you have lost” and pose three questions relating to peatlands’ functions, disturbances and methods:

1. “which valuable products or services did the damaged peatland formerly provide?
2. … which relevant properties of the peatland have been disturbed and have any irreversible changes taken place?
3. … which techniques must be applied to restore the relevant peatland functions?”

They classify degradation stages in six categories (the higher the category, the lower the restorability potential):



Figure 2: Peatland degradation stages

*Source: Schumann and Joosten (2012)*

As depicted in figure 2, restorability decreases with increased degradation. For stages 0 to 2, spontaneous regeneration occurs once the disturbing factor is removed and/ or the recent hydrologic changes are recovered. The ‘moderate’ state (stage 3) accounts for peatlands “where long lasting utilisation has changed the soil hydraulic properties but peat accumulation has continued” (Schumann and Joosten, 2014). Stages 4 and 5 denote “peatland of which the peat is irreversibly degraded by long-term drainage or where a strongly decomposed peat is surfacing as a result of peat mining” and “includes peatlands that have lost so much peat by mining, erosion or oxidation that the peatland body has got completely out of hydrological balance” (Schumann and Joosten. 2012). A suggested restoration strategy in Schumann and Joosten (2012) is to start by focusing efforts towards restoring the peatland components to the right of Figure 2 as they have more influence those to the left.

Peatland restoration measures and techniques vary depending on the specifics of each restoration project. Dohong (2017) summarises it as a “3Rs approach”:

1. Rewetting of peatlands (R1) which can entail canal blocking, canal backfilling and deep wells,
2. Revegetation (R2) by means of nursery, seedlings, seedlings transportation and natural regeneration,
3. and revitalization of local livelihoods (R3) which can result from paludiculture, aquaculture and/ or environment services based such as ecotourism.

Cris et al. (2014) highlight the most important principles of peatland restoration which involve: “maintain the permanent water saturation of the peat body and to stabilize water levels in a way that supports the peat forming vegetation and associated peatland wildlife” and, if need be, couple revegetating in addition to water management.

Dohong (2017) includes a summary of the goals, specific designs, infill materials and functionality of three types of peat rewetting techniques:



Figure 3: Peatland rewetting techniques

*Source: Dohong (2017)*

Peatland restoration involves several steps: from detailed planning, implementing, monitoring & reporting to project evaluation (Dohong, 2017). These are detailed on the figure 4 below:

****

Figure 4: Peatland restoration steps

*Source: Dohong (2017)*

A recent report by IUCN’s Peatland Programme (2014) on peatland restoration, includes an overview of several case studies in different countries across five continents:

1. Europe: United Kingdom, Poland, Sweden, Ireland and Belarus. The report includes several big restoration projects which use techniques such as drain blocking and tree removal. Private water companies in the North Penines “have funded large-scale restoration work as well as survey and monitoring to assess the water, carbon and biodiversity benefits. The resulting investment is cost effective for the businesses and provides extra support for local employment and economies.” (Cris et al., 2014). In Germany, “A pilot project in Lower Saxony shows that producing Sphagnum biomass as an alternative to extracting fossil peat for ‘growing media’ (horticultural potting soil) may help reduce the loss of pristine bog ecosystems” (Cris et al., 2014). After 10 years since the start of the project, led by Greifswald University, the methodologies developed demonstrate that not only Sphagnum farming “is possible and promising” but that it could even meet Germany’s peat horticulture needs (Cris et al., 2014).
2. Africa: South Africa and Rwanda. The report highlights the role peatlands play on daily subsistence, given the population is mainly rural both for cultivation, grazing as well as a source of protein and fibre (Cris et al., 2014). Government initiatives, such as South Africa’s Working for wetlands which aim “to maximise opportunities with respect to ecological integrity, water and food security, human well-being and poverty alleviation”, could be successful in raising awareness and promoting behavioral changes on peatland practices (Cris et al., 2014).
3. Asia: China, Indonesia and Bangladesh. In China, a range of restoration techniques have been implemented for the restoration of a peatland area on the Yellow river upper catchment. These include: canal blocking, fencing, re- vegetation, gullies blocking and concrete dams (Cris et al., 2014).
4. Oceania: Australia. In the Australian Alps, restoration techniques following the 2003 wildfires include: “shading and protection of the remnant bog and fen plant populations,… the construction of straw-bale ‘dams’ in flow-lines to create/restore surface pools; the construction of subsurface organic matter dams to slow the flow of water from the peats; and the placement of coir and straw-filled jute mesh ‘logs’ as surface water-spreaders and sediment traps.” Cris et al. (2014).
5. Americas: Canada. The horticultural industry along with government agencies and academic institutions have funded major restoration projects over the last two decades with the aim to accelerate the restoration of bogs, something crucial considering Canada’s role as “a major producer and exporter of peat for horticultural uses” (Cris et al., 2014).

The summarized case studies above depict the application of different restoration techniques depending on the objective. Joosten (2015) highlights that “the immediate benefit of peatland rewetting is in the fact that the net greenhouse gas emissions from rewetted peatlands are significantly lower compared to the previous drained situation”. In addition, the time it takes for the restored site to switch from a carbon source to a carbon sink ranges from 6 to 10 years up to 50 years. Section 2.5.1. analyses this in further detail.

Cris et al. (2014) stress on reduced grazing or burning as restoration options in less degraded peatlands to prevent further deterioration and higher restoring costs further ahead. In addition, the report stresses that “whilst the general principles of peatland restoration are well established more work is needed in developing techniques for the variety of different situations” with monitoring, scientific research, quantification of restoration benefits and good practices’ knowledge sharing being crucial strategies (Cris et al., 2014).

## Adoption Path

### Current Adoption

Literature on global restored peatland area is scarce. A recent overview on progress on peatland restoration in Western Europe over the past 25 years refers to the EU-LIFE programme investment of over 165 Mill. EUR with the aim to restore 913 km2 of peatland are in Western Europe but doesn’t clarify how much of that target has been actually achieved (Andersen et al., 2017). At present, the current adoption in 2014 is assumed to be zero, like in other restoration solutions.

### Trends to Accelerate Adoption

Policy initiatives at the government level, especially those with a longer-term frame are crucial for developing peatland restoration plans as well as access to funding. Three government initiatives have been identified:

1. Indonesia: The Peatland Restoration Agency was established in 2016 (after the peatland fires in Sep- Oct 2015), with the aim of restoring 20,000 of degraded peatlands by 2020 (World Bank, 2017; Crump et al., 2017). Given that progress on this target is not available, we extend the time for achieving the target up to 2040 when incorporating Indonesia’s peatland restoration target in scenario development.
2. Scotland: The Government’s climate change plan “sets targets to restore 50,000 hectares of degraded peatland by 2020, increasing to 250,000 hectares by 2030.”.
3. United Kingdom: The “UK Peatland strategy” aims for “two million hectares of peatland in good condition, under restoration or being sustainably managed by 2040” (IUCN UK, 2018). For the purpose of this analysis, we assume that Scotland’s target is included in the “UK Peatland strategy”.

There are other initiatives which are relevant to peatland restoration. Despite most of them do not contain specific restoration targets, these could be drivers for national policies. These include:

1. UN Convention on Biological Diversity- Strategic Plan for 2011- 2020 and the Aichi targets: “Peatlands ecosystems are to be restored and safeguarded for the provision of essential services and contribution to carbon stocks.” (Crump et al., 2017)
2. 2030 Agenda for Sustainable Development- SDG: “SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.” (Crump et al., 2017).
3. LIFE Peat restore: “Together with nine partners from Poland, Germany and the Baltic states the LIFE Climate Mitigation project “Peat Restore” was established in 2016. During five years the project aims to rewet degraded peatlands in the partner countries, covering an area of 5,300 hectares to restore the natural function as carbon sinks.”

<https://life-peat-restore.eu/en/>

1. Moor futures: launched in 2011, it is a voluntary carbon market that supports peatland restoration (Bonn et al., 2014).
2. Other initiatives: For instance, Wetlands International “in close collaboration with the Ministry of Natural Resources and Environment of the Russian Federation” and other partners, are implementing “one of the largest on-the-ground peatland restoration project in the world” in Russia (UNFCCC. (n.d.). The project followed the 2010 extensive peat fires in the Moscow region. At present, “over 35,000 hectares of drained peatlands have been restored using ecological methods with another 10,000 hectares currently underway”, and “the project is being scaled-up to reach from four to ten regions in Russia, which should ultimately cover at least 0.5 million hectares of ecologically restored peatlands” (UNFCCC).

Asides from national and global policies promoting peatland restoration, “a combination of public and private investment is likely to be needed” (Cris et al., 2014). In addition, new employment opportunities “from the development of innovative products such as Sphagnum farming in Germany and mosquito repellent in Indonesia or new ventures such as wildlife tourism or through the restoration and management of the peatland itself”, can contribute towards the long- term success of the restoration initiatives (Cris et al., 2014).

### Barriers to Adoption

Successful restoration both in the short and long- term depends on funding availability, the feasibility of scaling up restoration techniques and long- term planning (Cris et al., 2014).

### Adoption Potential

We assume that the adoption potential can reach 100% of TLA in one the Custom PDS adoption scenarios described below. However, successful restoration depends both on planning and sufficient funding. According to Andersen et al. (2017)’s review on Western Europe peatland restoration, “extensive damage combined with changes in environmental conditions mean that bringing back functional conditions may be impossible to achieve—at least not without investments which society may not be inclined to make.”

## Advantages and disadvantages of SOLUTION

### Similar Solutions

According to Andersen et al. (2017) analysis in Western Europe, “peatland restoration activities have been mostly undertaken in protected areas”. Further research on whether this is the case for other regions could help clarify this solution’s interaction with *Peatland protection*.

In addition, there might be a potential competition for funding sources with other restoration solutions such as *Tropical forest restoration*.

### Arguments for Adoption

The time it takes for a restored peatland to start carbon sequestration without anthropogenic interference is not clear. Weddington et al. (2010)’s analysis of a restored peatland area in Quebec conclude that “this degraded peatland ecosystem has not yet returned to a net carbon sink but will likely return to a net carbon sink in 6 to 10 years post restoration.”On the other hand, Samaritani et al. (2011)’s analysis of a cutover bog in Switzerland conclude that ““Our results show that re- establishing a Sphagnum cover is not sufficient to restore a CO2- sequestrating function but that after circa 50 years the ecosystem may naturally regain this function over the growing season.” Considering the controversy in the literature, Griscom et al. (2017)’s “choose to omit a sequestration benefit from peatland restoration in our calculations”.

Despite a consensus on the time it takes for a restored peatland to achieve stand- alone carbon sequestration is not clear from the literature review conducted for this report, Joosten (2015) highlights that “the immediate benefit of peatland rewetting is in the fact that the net greenhouse gas emissions from rewetted peatlands are significantly lower compared to the previous drained situation”. The significant decrease in emissions (as shown by the case studies included in the *peatland restoration* model) make a case for the mitigation benefits of this solution.

### Additional Benefits and Burdens

In addition to reduced GHG emissions vs. drained peatlands, additional benefits include: “flood protection and the provision of key habitat for many species” (Knox et al., 2015).

Here this solution is compared with other solutions in the food production cluster for farm, ecosystem, and social impacts.

Table 1.1 Food Production Solutions Comparison: On-Farm Impacts

**Yield Gains:** loss of yield “loss”,no impact “n/a”,1-9% low, 10-24% medium, 25%+ high. **First Cost**: Free is $0**,** Low is $1-100, Medium is $100-500, Expensive is $500+. **Net Profit Margin:** Low is $0-100/ha, Medium is $100-500, High is $500+. **Delayed Profit Period:** Short is 0-2, Mid is 3-6, Long is 6+

|  | **Yield Gains** | **Startup Cost** | **Net Profit** | **Delayed Profit Period** |
| --- | --- | --- | --- | --- |
| Conventional cropping | n/a | n/a | Medium | n/a |
| Conventional grazing | n/a | n/a | Medium | n/a |
| Conservation agriculture | Low | Medium | High | Mid |
| Farmland restoration | High | Medium | Medium | Short |
| Farm water use efficiency | n/a | Expensive | Medium | Short |
| Improved rice | Loss | Free | High | Mid |
| Managed grazing | Medium | Medium | Medium | Mid |
| Multistrata agroforestry | n/a | Expensive | High | Long |
| Nutrient management | n/a | Free | Low | Short |
| Regenerative agriculture | Low | Medium | High | Mid |
| Silvopasture | Medium | Expensive | High | Long |
| System of Rice Intensification | High | Free | High | Mid |
| Tree intercropping | Low | Expensive | Medium | Long |
| Tropical staple tree crops | High | Expensive | High | Long |
| Women smallholders | high | Free | High | Short |

Table 1.2 Food Production Solutions Comparison: On-Farm Impacts Social and Ecological Impacts

**Ecosystem Services** is subjective based on impacts on biodiversity, water quality, etc. **Social Justice Benefits:** Is solution Targeted to disadvantaged producers like smallholders and women, Relevant to them, or Not Applicable (n/a). **Climate Impacts per Hectare:** Low 0-3.7 t CO2-eq/ha/yr (0-1tC),Medium 3.8-11.0 t CO2-eq/yr (1-3 tC), High 11.1+ tCO2-eq/yr (3+tC). **Global Adoption Potential:** Low 0-100Mha, Medium 101-500 Mha, High 500+ Mha

|  | **Ecosystem Services** | **Social Justice Benefits** | **Climate Impact/ha** | **Global Adoption Potential** |
| --- | --- | --- | --- | --- |
| Conventional cropping | n/a | n/a | n/a | n/a |
| Conventional grazing | n/a | n/a | n/a | n/a |
| Conservation agriculture | Low | Relevant | Low | Medium |
| Farmland restoration | Medium | Relevant | Medium | Medium |
| Farm water use efficiency | Low | Relevant | Low | Medium |
| Improved rice | Medium | Relevant | high | Low-medium |
| Managed grazing | Low | Relevant | Low | Medium-high |
| Multistrata agroforestry | High | Relevant | High | Low |
| Nutrient management | Medium | Relevant | Low | High |
| Regenerative agriculture | Medium | Relevant | Low | Medium-high |
| Silvopasture | High | Relevant | High | Low-medium |
| System of Rice Intensification | Medium | Targeted | Medium | Low |
| Tree intercropping | High | Relevant | Medium | Medium |
| Tropical staple tree crops | Medium | Relevant | High | Low-medium |
| Women smallholders | n/a | Targeted | Low | Low |

# Methodology

## Introduction

Project Drawdown’s models are developed in Microsoft Excel using standard templates that allow easier integration with each other since integration is critical to the bottom-up approach used. The template used for this solution was the Land Model which accounts for sequestration of carbon dioxide from the atmosphere into plant biomass and soil, and reduction of emissions for a solution relative to a conventional practice. These practices are assumed to use land of a specific type that may be shared across several solutions. The actual and maximum possible adoptions are therefore defined in terms of land area (million hectares). The adoptions of both conventional and solution were projected for each of several Drawdown scenarios from 2015 to 2060 (from a base year of 2014) and the comparison of these scenarios with a reference (for the 2020-2050 segment[[1]](#footnote-1)) is what constituted the results.

*Agency Level*

The Government is the agency level for this solution. However, it should be noted that the role of NGOs, the horticultural industry as well as academic institutions is also crucial to restoration success at the global level.

## Data Sources

Key data sources include Joosten (2010) and Joosten (2015) which included 2008 and 2015 global degraded peatland area which were used to estimate the 2014 TLA value. Joosten (2015) also provided input for the avoided emissions data points together with 6 other peer- reviewed papers.

## Total Available Land

Drawdown’s agricultural production and land use model approach defines the Total Land Area as the area of land (in million hectares) suitable for adoption a given solution. Data on global land is acquired from Global Agro-Ecological Zones database, developed by the Food and Agriculture Organization of the United Nations (FAO) and the International Institute for Applied Systems Analysis (IIASA). The Drawdown Land-Use Model categorizes and allocates land according to agro-ecological zones based on the following factors: thermal climate, moisture regimes, soil quality, slope, cover type, and degradation status. These characteristics influence the suitability of different practices, and solution adoption scenarios are restricted by one or more of these factors.

Determining the total available land for a solution is a two-part process. The technical potential is based on: current land cover or land use; the suitability of climate, soils, and slopes; and on degraded or non-degraded status. In the second stage, land is allocated using the Drawdown Agro-Ecological Zone model, based on priorities for each class of land. The total land allocated for each solution is capped at the solution’s maximum adoption in the *Optimum* Scenario. Thus, in most cases the total available land is less than the technical potential.

Total land allocated for the *peatland restoration* solution is 62 million hectares, comprising global degraded peatlands. The total land area available for this solution was modeled using the 2008 and 2015 global degraded peatland areas included in Joosten (2010) and Joosten (2015) of 42.6 and 65 million hectares respectively. It is assumed that once the peatland is restored, it is no longer subject to further degradation which means that 100% of 2014 TLA can be achieved in 2050. Current adoption of *peatland restoration* is estimated at 0 million hectares (as detailed on section 1.2.1.). Despite several restoration projects have been on- going for several years, specific figures on complete restoration peatland area are very scarce.

## Adoption Scenarios

Two different types of adoption scenarios were developed: a Reference (REF) Case which was considered the baseline, where not much changes in the world, and a set of Project Drawdown Scenarios (PDS) with varying levels of ambitious adoption of the solution. Published results show the comparison of one PDS to the REF, and therefore focus on the change to the world relative to a baseline.

Five custom adoption scenarios were developed using national peatland restoration commitments scaled up at the global level for three of them and linear increases up to percentages of TLA (related to these restoration commitments) for the other two. The national commitments include:

1. United Kingdom: The UK’s Peatland Strategy for 2018- 2040 target for 2040 aims for ““Two million hectares of peatland in good condition, under restoration or being sustainably managed by 2040.” (IUCN, 2018). According to the same report, the UK peatland area is 2.6 million hectares, out of which only 20% remain in a “near- natural state”. Hence, the 2 Mha commitment represents 96% of the degraded peatland area.
2. Indonesia: Following the large forest and peatland fires in 2015, the Government set up the Peatland Restoration Agency (Badan Restorasi Gambut- BRG) in 2016 with the ambitious goal “to coordinate and drive the ambitious goal to restore 20,000 km2 of degraded peatlands by 2020 (World Bank, 2017).” (Crump et al., 2017). This 2 Mha target represents 49% of total degraded peatland area (4 Mha according to Uda et al. (2017)). Progress on this highly ambitious target is unclear with respect to actual restored peatland area and hence we take a conservative approach and extend it up to 2040 for the purpose of developing our scenarios.

Details on the five custom adoption scenarios are given below:

1. ***Custom adoption scenario one***: Scenario 1 is based on Indonesia and the UK commitments on peatland restoration. The weighted average of both commitments is 65% of degraded peatland area. As explained above, we take a conservative approach and assume there will be a linear increase up to 65% of TLA in 2040.
2. ***Custom adoption scenario two***: Scenario 2 assumes a linear increase up to 70% of TLA by 2040, exploring a scenario slightly more optimistic than the commitment- based scenario 1
3. ***Custom adoption scenario five***: Scenario 5 assumes a linear increase up to 100% of TLA by 2040, exploring a scenario slightly more optimistic than the scaling- up of UK’s Peatland Strategy goal
4. ***Custom adoption scenario six***: Scenario 6 scales up the UK’s peatland restoration commitment - which represents 96% of their total degraded peatland area- to the TLA assuming a linear increase up to its 96% by 2040.
5. ***Custom adoption scenario seven***: Scenario 7 scales up Indonesia’s peatland restoration commitment - which represents 49% of their total degraded peatland area- to the TLA assuming a linear increase up to its 49% by 2040.

Impacts of increased adoption of *peatlands*from 2020-2050 were generated based on three growth scenarios, which were assessed in comparison to a *Reference*Scenario where the solution’s market share was fixed at the current levels.

### Reference Case / Current Adoption

Current adoption is set at zero million hectares, following the explanation on section 1.2.1.

### Project Drawdown Scenarios

Three Project Drawdown scenarios (PDS) were developed for each solution, to compare the impact of an increased adoption of the solution to a reference case scenario, being:

#### Plausible Scenario - – This scenario is “low of all” custom PDS adoption scenarios.

#### Drawdown Scenario – This scenario is the “average of all” custom adoption scenarios

#### Optimum Scenario –– This scenario is “high of all” custom PDS adoption scenarios.

## Inputs

### Climate Inputs

Aggregate emissions reductions are set at 16.5 tons of carbon dioxide equivalent per hectare per year based on a meta-analysis of 15 data points from 6 sources. Carbon dioxide emissions reduction are set at 7 tons of carbon dioxide per hectare based on 8 data points from 1 source. The 7 peer- reviewed sources are based on the difference in emissions between drained and restored sites. For most of the case studies, results showed some carbon sequestration after restoration but not for all of them. For instance, Strack and Zuback (2013) study on the annual carbon balance of a former horticultural peatland in Canada after 10 years of restoration resulted in “due to dry conditions during the study year all sites acted as net carbon sources with annual balance of the natural, restored and unrestored sites of 250.7, 148.0 and 546.6 gC/m2respectively.” Despite restoration did not result in the peatland acting as a carbon sink for this particular study and measurements, the emissions from the restored site represent less than a third of the emissions from the unrestored site and are lower even than those from the natural peatland site.

The literature review on the estimated time it takes for a restored peatland to return to acting as a carbon sink varies widely: from 6- 10 years (Waddington et al., 2010), 13 (Hambley et al., 2019), 15 (Schrier- Uijl et al., 2013; Gunther et al., 2015), 17 (Lucchese et al, 2010) up to 20- 30 (Rochefort et al., 2003) to even 50 years (Samaritani et al., 2011). Given the wide range of results, it was decided not to model carbon sequestration and base the model on the case studies which focus on the difference in emissions between restored and unrestored sites. Our approach is in line with Griscom et al. (2017): “Due to controversy in the literature about the timing and net atmospheric effect of methane emissions in restored peatlands, we choose to omit a sequestration benefit from peatland restoration in our calculations”.

Table 2.1 Climate Inputs

|  | **Units** | **Project Drawdown Data Set Range** | **Model Input** | **Data Points (#)** | **Sources (#)** |
| --- | --- | --- | --- | --- | --- |
| Aggregate emissions reduction | *tCO2 eq./ha/yr* | 11.1- 21.9 | 16.5 | 15 | 6 |
| Carbon dioxide emissions reduction | *tCO2/ ha* | 5.1- 8.9 | 7.0 | 8 | 1 |

Note: Project Drawdown data set range is defined by the low and high boundaries which are respectively 1 standard deviation below and above the mean of the collected data points[[2]](#footnote-2).

*Modeling Saturation*

Biosequestration does not have limitless potential. In most cases, there is a maximum amount of carbon that can be stored in soils and aboveground perennial biomass before they become saturated. Biosequestration continues after saturation but is offset by more or less equal emissions. In most cases soils, and biomass can return to their approximate pre-agricultural or pre-degradation levels of carbon. This takes anywhere between 10-50 years in agricultural cases, and sometimes somewhat longer in the case of ecosystems like forests. Data about saturation time is very limited.

The Drawdown land model takes the conservative approach that all land units currently adopted for agricultural solutions (including multistrata agroforestry) have already achieved saturation, and will not be contributing additional sequestration. New adopted land is assumed to sequester for at least 30 years before achieving saturation.

Note that there are some important exceptions to saturation. Certain ecosystems continue to sequester soil carbon for centuries, notably peatlands and coastal wetlands. Some scientists argue that tropical forests can continue to sequester carbon at a slower rate after saturation. The addition of biochar to saturated soils may be able to overcome this constraint, as does the use of biomass from bamboo or afforestation in long-term products like buildings.

### Financial Inputs

Financials are not modeled

### Other Inputs

There are none.

## Assumptions

Six overarching assumptions have been made for Project Drawdown models to enable the development and integration of individual model solutions. These are that infrastructure required for solution is available and in-place, policies required are already in-place, no carbon price is modeled, all costs accrue at the level of agency modeled, improvements in technology are not modeled, and that first costs may change according to learning. Full details of core assumptions and methodology will be available at [www.drawdown.org](http://www.drawdown.org). Beyond these core assumptions, there are other important assumptions made for the modeling of this specific solution. These are detailed below.

1. The deforestation will continue with the current rate of deforestation both under the solution and the conventional case.
2. Efforts will be laid at the national and international level to protect peatland resources on an urgency basis, considering the high carbon stock in the peatland areas and their limited availability.
3. Leakage effect which is defined as “the unanticipated decrease or increase in GHG benefits outside of the project's accounting boundary (the boundary defined for the purposes of estimating the project's net GHG impact) as a result of project activities. For example, conserving forests that otherwise would have been deforested for agricultural land may displace farmers to an area outside of the project's boundaries. There, the displaced farmers may engage in deforestation-and the resulting carbon emissions are referred to as leakage (IPCC)" is considered in the present modeling of the solution. Thus, in the present model, it is assumed that protection of peatland in the solution case will lead to some sort of leakage in the adjacent areas of the reference case. However, the leakage related degradation is a time bound phenomenon and gets stabilized after some years; which is uncertain to estimate at the global level. Therefore, to incorporate the leakage effect, in the present protect model, it is assumed that the carbon benefits of protecting the peatlands will be realized one year later.
4. It is assumed that the re-growth of the degraded peatland area will start one year later after the peatland will be brought under protection.
5. Assumption for incorporating the delay in impact due to the time taken by the agencies to actually bring a peatland under protection - It is assumed that the required agency level legalities to bring a peatland under protection will be in place by the year of adoption. Thus, there will be no delay in the climate benefits resulting from a delay in agency level efforts to bring a peatland area under protection. Therefore the "year of protection" is assumed to be the "year of implementation".

## Integration

The complete Project Drawdown integration documentation (will be available at [www.drawdown.org](http://www.drawdown.org)) details how all solution models in each sector are integrated, and how sectors are integrated to form a complete system. Those general notes are excluded from this document but should be referenced for a complete understanding of the integration process. Only key elements of the integration process that are needed to understand how this solution fits into the entire system are described here.

*Peatland restoration* is part of Drawdown’s Land Use sector. Within this sector, it is part of a cluster of solutions-based ecosystem restoration.

***The Agroecological Zone model***

Drawdown’s approach seeks to model integration between and within sectors, and avoid double counting. Several tools were developed to assist in this effort. The Agroecological Zone (AEZ) model categorizes the world’s land by: current cover (e.g. forest, grassland, cropland), thermal climate, moisture regime, soil quality, slope, and state of degradation.  Both Food (supply-side) and Land Use solutions were assigned to AEZs based on suitability. Once current solution adoption was allocated for each zone (e.g. semi-arid cropland of minimal slopes), zone priorities were generated and available land was allocated for new adoption. Priorities were determined based on an evaluation of suitability, consideration of social and ecological co-benefits, mitigation impact, yield impact, etc. For example, *Indigenous peoples’ land management* is given a higher priority than *forest protection* for AEZs with forest cover, in recognition of indigenous peoples’ rights and livelihoods. *Multistrata agroforestry* is highly prioritized in tropical humid climates due to its high sequestration rate, food production, and highly limited climate constraints.

Each unit of land was allocated to a separate solution to avoid overlap between practices. The exception to this are *farmland irrigation*, *nutrient management*, and *women smallholders*, which can be implemented in addition to other practices. The constraint of limited available land meant that many solutions could not reach their technical adoption potential. The AEZ model thus prevents double-counting for adoption of agricultural and land use solutions.

Drawdown’s agricultural production and land use model approach defines the Total Land Area as the area of land (in million hectares) suitable for adoption a given solution. Data on global land is acquired from Global Agro-Ecological Zones database, developed by the Food and Agriculture Organization of the United Nations (FAO) and the International Institute for Applied Systems Analysis (IIASA). The Drawdown Land-Use Model categorizes and allocates land according to agro-ecological zones based on the following factors: thermal climate, moisture regimes, soil quality, slope, cover type, and degradation status. These characteristics influence the suitability of different practices, and solution adoption scenarios are restricted by one or more of these factors.

Determining the total available land for a solution is a two-part process. The technical potential is based on: current land cover or land use; the suitability of climate, soils, and slopes; and on degraded or non-degraded status. In the second stage, land is allocated using the Drawdown Agro-Ecological Zone model, based on priorities for each class of land. The total land allocated for each solution is capped at the solution’s maximum adoption in the *Optimum* Scenario. Thus, in most cases the total available land is less than the technical potential.

Given that *peatland restoration* is a new solution, a customized TLA was calculated as detail in section 2.3.

## Limitations/Further Development

Currently, a limitation of this study is the lack of global datasets including current adoption and restoration commitments (both at the government and private sector levels).

# Results

## Adoption

Below are shown the world adoptions of the solution in some key years of analysis in functional units and percent for the three Project Drawdown scenarios.

Total adoption in the *Plausible* Scenario is 35.16 million hectares in 2050, representing 57 percent of the total suitable land. Of this, 29.27 million hectares are adopted from 2020-2050.

Total adoption in the *Drawdown* Scenario is 47.04 million hectares in 2050, representing 76 percent of the total suitable land. Of this, 39.12 million hectares are adopted from 2020-2050.

Total adoption in the *Optimum* Scenario is 58.92 million hectares in 2050, representing 95 percent of the total suitable land. Of this, 48.96 million hectares are adopted from 2020-2050.

Table 3.1 World Adoption of the Solution

| **Solution** | **Units** | **Base Year (2014)** | **New Adoption by 2050** | | |
| --- | --- | --- | --- | --- | --- |
| **Plausible** | **Drawdown** | **Optimum** |
| Peatland restoration | Mha | 0 | 35.16 | 47.04 | 58.92 |
| % Total Land Available | 0 | 57 | 76 | 95 |

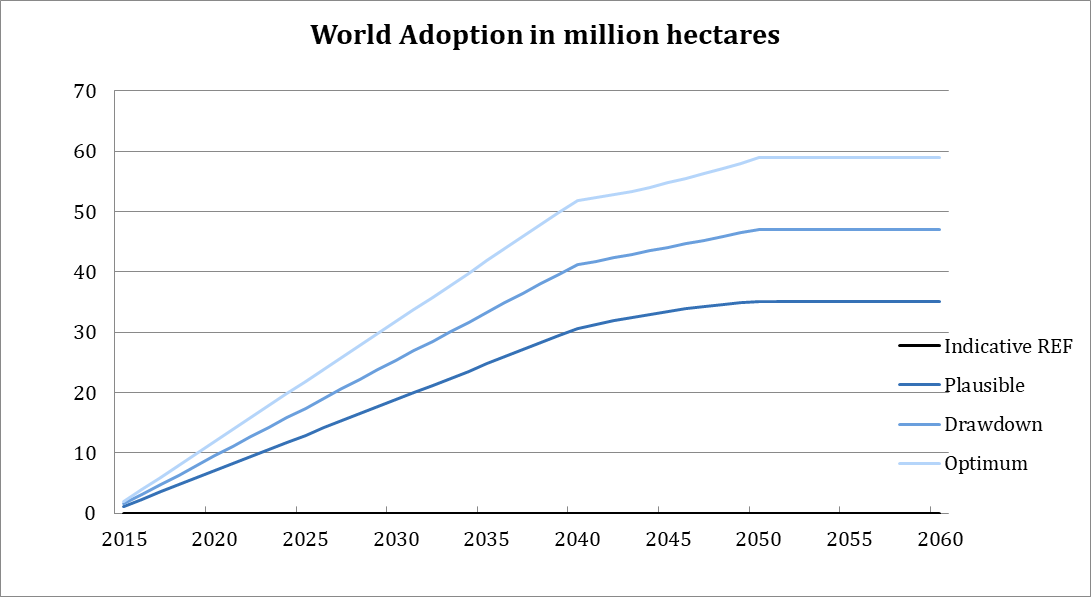


Figure 3.1 World Annual Adoption 2020-2050

## Climate Impacts

Below are the emissions results of the analysis for each scenario which include total emissions reduction, atmospheric concentration changes, and sequestration where relevant. For a detailed explanation of each result, please see the glossary (Section 6).

Climate impact is 12.1, 16.1, and 20.2 gigatons of carbon-dioxide equivalent in the *Plausible, Drawdown,* and *Optimum* Scenarios respectively.

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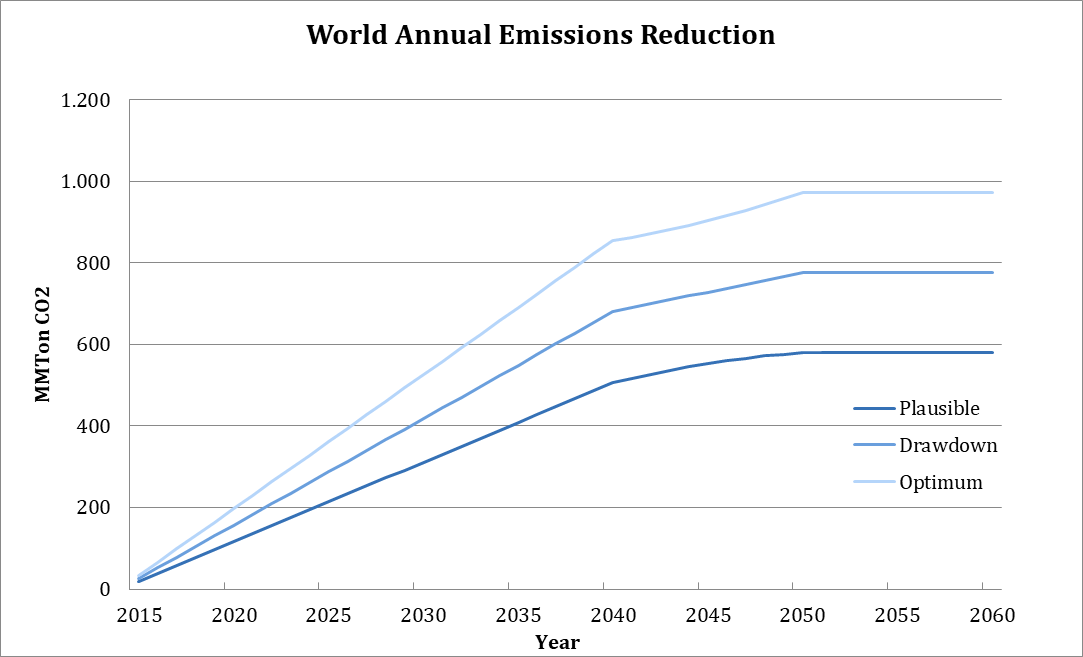
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Figure 3.2 World AnnualGreenhouse Gas Emissions Reduction

| **Scenario** | **Maximum Annual Emissions Reduction** | **Total Emissions Reduction** | **Max Annual CO2 Sequestered** | **Total Additional CO2 Sequestered** | **Total Atmospheric CO2-eq Reduction** | **Emissions Reduction in 2030** | **Emissions Reduction in 2050** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *(Gt CO2-eq/yr.)* | *Gt CO2-eq/yr. (2020-2050)* | *(Gt CO2-eq/yr.)* | *Gt CO2-eq/yr. (2020-2050)* | Gt CO2-eq (2020-2050) | (Gt CO2-eq/year) | *(Gt CO2-eq/year)* |
| ***Plausible*** | 0.58 | 12.07 | - | - | 12.07 | 0.31 | 0.58 |
| ***Drawdown*** | 0.78 | 16.13 | - | - | 16.13 | 0.42 | 0.78 |
| ***Optimum*** | 0.97 | 20.18 | - | - | 20.18 | 0.53 | 0.97 |

Table 3.2 Climate Impacts

The solution was integrated with all other Project Drawdown solutions and may have different emissions results from the models. This is due to adjustments caused by interactions among solutions that limit full adoption (such as by feedstock or demand limits) or that limit the full benefit of some solutions (such as reduced individual solution impact when technologies are combined).

| **Scenario** | **GHG Concentration Change in 2050** | **GHG Concentration Rate of Change in 2050** |
| --- | --- | --- |
| *PPM CO2-eq (2050)* | *PPM CO2-eq change from 2049-2050* |
| **Plausible** | - | - |
| **Drawdown** | - | - |
| **Optimum** | - | - |

Table . Impacts on Atmospheric Concentrations of CO2-eq

## Financial Impacts

Financials are not modelled.

# Discussion

## Limitations

Projecting financials at the government or non-governmental organization level is also recommended.

## Benchmarks

The Drawdown model calculates emissions reduction of 0.31-0.53 gigatons carbon dioxide-equivalent per year by 2030 which is within the range of Griscom et al (2017)’s “Natural climate solutions” that calculates 0.15-0.85 gigatons of carbon dioxide equivalent per year in 2030.

| **Source and scenario** | **Mitigation Impact (i.e. Gt CO2-eq in 2030)** |
| --- | --- |
| Griscom et al. (2017) | 0.15- 0.85 |
| *Plausible* Scenario | 0.31 |
| *Drawdown* Scenario | 0.42 |
| *Optimum* Scenario | 0.53 |

Table 4.1 Benchmarks

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# Glossary

**Adoption Scenario** – the predicted annual adoption over the period 2015 to 2060, which is usually measured in **Functional Units**. A range of scenarios is programmed in the model, but the user may enter her own. Note that the assumption behind most scenarios is one of growth. If for instance a solution is one of reduced heating energy usage due to better insulation, then the solution adoption is translated into an increase in use of insulation. There are two types of adoption scenarios in use: **Reference (REF)** where global adoption remains mostly constant, and **Project Drawdown Scenarios (PDS)** which illustrate high growth of the solution.

**Approximate PPM Equivalent** – the reduction in atmospheric concentration of CO2 (in **PPM**) that is expected to result if the **PDS Scenario** occurs. This assumes a discrete avoided pulse model based on the Bern Carbon Cycle model.

**Average Abatement Cost** – the ratio of the present value of the solution (**Net** **Operating Savings** minus **Marginal First Costs**) and the **Total Emissions Reduction**. This is a single value for each solution for each **PDS Scenario**, and is used to build the characteristic “*Marginal Abatement Cost*” curves when Average Abatement Cost values for each solution are ordered and graphed.

**Average Annual Use** – the average number of functional units that a single implementation unit typically provides in one year. This is usually a weighted average for all users according to the data available. For instance, total number of passenger-km driven by a hybrid vehicle in a year depends on country and typical number of occupants. We take global weighted averages for this input. This is used to estimate the **Replacement Time**.

**Cumulative First Cost** – the total **First Cost** of solution **Implementation Units** purchased in the **PDS Scenario** in the analysis period. The number of solution implementation units that are available to provide emissions reduction during the analysis period is dependent on the units installed prior to the analysis period, and hence all implementation units installed after the base year are included in the cumulative first costing (that is 2015-2050).

**Direct Emissions** – emissions caused by the operation of the solution, which are typically caused over the lifetime of the solution. They should be entered into the model normalized per functional unit.

**Discount Rate**- the interest rate used in discounted cash flow (DCF) analysis to determine the present value of future cash flows. The discount rate in DCF analysis takes into account not just the time value of money, but also the risk or uncertainty of future cash flows; the greater the uncertainty of future cash flows, the higher the discount rate. Most importantly, the greater the discount rate, the more the future savings are devalued (which impacts the financial but not the climate impacts of the solution).

**Emissions** **Factor**– the average normalized emissions resulting from consumption of a unit of electricity across the global grid. Typical units are kg CO2e/kWh.

**First Cost**- the investment cost per **Implementation Unit** which is essentially the full cost of establishing or implementing the solution. This value, measured in 2014$US, is only accurate to the extent that the cost-based analysis is accurate. The financial model assumes that the first cost is made entirely in the first year of establishment and none thereafter (that is, no amortization is included). Thus, both the first cost and operating cost are factored in the financial model for the first year of implementation, all years thereafter simply reflect the operating cost until replacement of the solution at its end of life.

**Functional Unit** – a measurement unit that represents the value, provided to the world, of the function that the solution performs. This depends on the solution. Therefore, LED Lighting provides petalumen-hours of light, Biomass provides tera-watt-hours of electricity and high speed rail provides billions of passenger-km of mobility.

**Grid Emissions** – emissions caused by use of the electricity grid in supplying power to any operation associated with a solution. They should be in the units described below each variable entry cell. Drawdown models assume that the global electric grid, even in a Reference Scenario, is slowly getting cleaner, and that emissions factors fall over time resulting in lower grid emissions for the same electricity demand.

**Implementation Unit** – a measurement unit that represents how the solution practice or technology will be installed/setup and priced. The implementation unit depends on the solution. For instance, implementing electric vehicles (EV) is measured according to the number of actual EV’s in use, and adoption of Onshore Wind power is measured according to the total terawatts (TW) of capacity installed worldwide.

**Indirect Emissions** – emissions caused by the production or delivery or setup or establishment of the solution in a specified area. These are NOT caused by day to day operations or growth over time, but they should be entered into the model normalized on a per functional unit or per implementation unit basis.

**Learning Rate/Learning Curve** - Learning curves (sometimes called experience curves) are used to analyze a well-known and easily observed phenomenon: humans become increasingly efficient with experience. The first time a product is manufactured, or a service provided, costs are high, work is inefficient, quality is marginal, and time is wasted. As experienced is acquired, costs decline, efficiency and quality improve, and waste is reduced. The model has a tool for calculating how costs change due to learning. A 2% learning rate means that the cost of producing a *good* drops by 2% every time total production doubles.

**Lifetime Capacity** – this is the total average functional units that one implementation unit of the solution or conventional technology or practice can provide before replacement is needed. All technologies have an average lifetime usage potential, even considering regular maintenance. This is used to estimate the **Replacement Time**. and has a direct impact on the cost to install/acquire technologies/practices over time. E.g. solar panels generate, on average, a limited amount of electricity (in TWh) per installed capacity (in TW) before a new solar panel must be purchased. Electric vehicles can travel a limited number of passenger kilometers over its lifetime before needing to be replaced.

**Lifetime Operating Savings**–the operating cost in the PDS versus the REF scenarios over the lifetime of the implementation units purchased during the model period regardless of when their useful life ends.

**Lifetime Cashflow NPV**-the present value (PV) of the net cash flows (PDS versus REF) in each year of the model period (2015-2060). The net cash flows include net operating costs and first costs. There are two results in the model: Lifetime Cashflow NPV for a Single **Implementation Unit**, which refers to the installation of one **Implementation Unit**, and Lifetime Cashflow NPV of All Units, which refers to all **Implementation Units** installed in a particular scenario. These calculations are also available using profit inputs instead of operating costs.

**Marginal First Cost** – the difference between the **First Cost** of all units (solution and conventional) installed in the **PDS Scenario** and the **First Cost** of all units installed in the **REF Scenario** during the analysis period. No discounting is performed. The number of solution implementation units that are available to provide emissions reduction during the analysis period is dependent on the units installed prior to the analysis period, and hence all implementation units installed after the base year are included in the cumulative first costing (that is 2015-2050).

**Net Annual Functional Units (NAFU)** – the adoption in the PDS minus the adoption in the REF in each year of analysis. In the model, this represents the additional annual functional demand captured either by the solution in the **PDS Scenario** or the conventional in the **REF Scenario**.

**Net Annual Implementation Units (NAIU)** – the number of **Implementation Units** of the solution that are needed in the PDS to supply the **Net Annual Functional Units (NAFU).** This equals the adoption in the PDS minus the adoption in the REF in each year of analysis divided by the average annual use.

**Net Operating Savings** – The undiscounted difference between the operating cost of all units (solution and conventional) in the **PDS Scenario** minus that of all units in the **REF Scenario**.

**Operating Costs** – the average cost to ensure operation of an activity (conventional or solution) which is measured in 2014$US/**Functional Unit**. This is needed to estimate how much it would cost to achieve the adoption projected when compared to the **REF Case**. Note that this excludes **First Costs** for implementing the solution.

**Payback Period** – the number of years required to pay all the **First Costs** of the solution using **Net Operating Savings**. There are four specific metrics each with one of **Marginal First Costs** or **First Costs** of the solution only combined with either discounted or non-discounted values. All four are in the model. Additionally, the four outputs are calculated using the increased profit estimation instead of **Net Operating Savings**.

**PDS/ Project Drawdown Scenario** – this is the high growth scenario for adoption of the solution

**PPB/ Parts per Billion** – a measure of concentration for atmospheric gases. 10 million PPB = 1%.

**PPM/ Parts per Million** – a measure of concentration for atmospheric gases. 10 thousand PPM = 1%.

**REF/ Reference Scenario** – this is the low growth scenario for adoption of the solution against which all **PDS scenarios** are compared.

**Regrets solution** has a positive impact on overall carbon emissions being therefore considered in some scenarios; however, the social and environmental costs could be harmful and high.

**Replacement Time**- the length of time in years, from installation/acquisition/setup of the solution through usage until a new installation/acquisition/setup is required to replace the earlier one. This is calculated as the ratio of **Lifetime Capacity** and the **Average Annual Use**.

**TAM/ Total Addressable Market** – represents the total potential market of functional demand provided by the technologies and practices under investigation, adjusting for estimated economic and population growth. For this solutions sector, it represents world and regional total addressable markets for electricity generation technologies in which the solutions are considered.

**Total Emissions Reduction** – the sum of grid, fuel, indirect, and other direct emissions reductions over the analysis period. The emissions reduction of each of these is the difference between the emissions that would have resulted in the **REF Scenario** (from both solution and conventional) and the emissions that would result in the **PDS Scenario**. These may also be considered as “emissions avoided” as they may have occurred in the REF Scenario, but not in the PDS Scenario.

**Transition solutions** are considered till better technologies and less impactful are more cost effective and mature.

**TWh/ Terawatt-hour** – A unit of energy equal to 1 billion kilowatt-hours

1. For most results, only the differences between scenarios, summed over 2020-2050 were presented, but for the net first cost, the position was taken that to achieve the adoptions in 2020, growth must first happen from 2015 to 2020, and that growth comes at a cost which should be accounted for, hence net first cost results represent the period 2015-2050. [↑](#footnote-ref-1)
2. In some cases, the low boundary is negative for a variable that can only be positive, and in these cases the lowest collected data point is used as the “low” boundary. [↑](#footnote-ref-2)