**The Drawdown Biomass Model Methodology**

**Abstract**

Climate change mitigation involves multiple approaches in different sectors, including many that impact the global demand and supply of biomass. Forest protection reduces biomass availability, while agroforestry and dedicated perennial biomass on anthropogenic grassland increase supply. Some solutions reduce demand for biomass, while many solutions require it as a feedstock. The Drawdown Biomass Model was developed to integrate these multiple factors, determine if biomass surpluses are available, and allocate any surpluses to the solutions that require biomass. Surpluses are available in both Scenario 1 (2˚C warming) and 2 (1.5˚C warming), and are able to meet the needs of 8 mitigation solutions that require biomass feedstocks.

**Introduction**

The Drawdown Biomass Model is an integration model that connects solutions across sectors including ecosystem management and protection, agriculture, oceans, electricity generation, industry, manufactured sinks, and transportation. It was designed to answer questions about the complex interactions of ecosystem protection and restoration, and the production and utilization of timber and other forms of biomass. The central questions are can the combined impact of Drawdown’s solutions meet projected timber and biomass demand during the period 2014-2050, and how much surplus biomass is available for the many mitigation solutions that use it as a feedstock?

The Biomass Model must be placed in context of the Food Supply integration model, which determined that food demand is met for each year through 2050 without deforestation in both Scenarios 1 and 2. With the food supply secured, Drawdown turned its attention to the need for biomass, to determine what additional mitigation was possible. In this way the food versus fuel (food versus feedstock) debate can be resolved: for Drawdown, food comes first, and only what feedstocks can be produced in the context of forest restoration and available land are available for mitigation solutions that require them.

The model integrates demand- and supply-side solutions. See Table 1. Some Drawdown solutions reduce the demand for biomass, including *improved clean cookstoves, biogas for cooking,* and *recycled paper.* Others increase demand including *biomass power, insulation, district heating, bioplastic, biochar,* and the coming attractions *building with wood* and *2nd generation biofuels.* Some solutions reduce the supply of biomass, including *forest protection, peatland protection, coastal wetlands protection*, and *Indigenous Peoples’ forest tenure.* Other solutions increase the supply of biomass, notably *tree plantations, bamboo production, perennial biomass, sustainable intensification, tree intercropping, silvopasture, multistrata agroforestry,* and *perennial staple crops*, along with the coming attraction *seaweed farming.* The Biomass Model integrates these solutions to determine the net demand and supply of biomass for the period 2020-2050 in three scenarios.

Table 1 Solutions and models integrated in the Biomass model

|  |  |
| --- | --- |
| **Demand-Side** | **Solutions** |
| Electricity | *Biomass power* |
| Buildings | *Improved clean cookstoves, biogas for cooking, insulation, district heating, building with wood\** |
| Industry | *Recycled paper, bioplastic* |
| Manufactured sinks | *Biochar* |
| Transportation | *2nd generation biofuels\** |
| **Supply-Side** | **Solutions** |
| Ecosystem protection & management | *Forest protection, peatland protection, coastal wetlands protection, Indigenous People’s forest tenure* |
| Biomass production | *Tree plantations (on degraded land), bamboo production, perennial biomass* |
| Agriculture | *Sustainable intensification\*, Food Supply integration model, tree intercropping, silvopasture, multistrata agroforestry, perennial staple crops, biochar* |
| Oceans | *Seaweed farming\** |

\*Solutions under development but not yet full developed.

Three scenarios are modeled from 2020-2050, including Scenario 1 (roughly 2˚C of warming) and Scenario 2 (roughly 1.5˚C of warming), as well as a business-as-usual scenario. For each scenario, baseline demand is modified due to the adoption of demand reduction solutions. Supply is adjusted based on adoption of solutions that increase or decrease biomass availability. Surpluses are allocated to mitigation solutions that require biomass as a feedstock.

**Literature Review**

Piotrowski (2015) developed a model that integrates global biomass supply and demand, including wood and crop residues as well as crops and grazed biomass. Several demand reduction approaches are incorporated, as are various assumptions about demand for a biobased economy. Greatly increased biomass demand is demonstrated in the biobased economy scenarios.

Many mitigation approaches require biomass as a feedstock. The approach receiving the most attention at the moment is BioEnergy Carbon Capture and Storage (BECCS, not modeled by Drawdown). The IPCC notes that producing feedstocks for BECCS would require some 300-700 Mha (IPCC 2019 *Climate Change and Land* Chapter 6).

The IPCC *Climate Change and Land* report (Chapter 6) assesses the mitigation potential and adverse impacts of a range of land- and food-related practices. This includes many practices integrated into the Drawdown Biomass Model. Increased food productivity, agroforestry, and improved forest management are rated as having medium to large benefits across the five land challenges of mitigation, adaptation, desertification, land degradation, and food security. Afforestation and production of biomass feedstocks for biochar and BECCS are flagged as resulting in competition for land. While most mitigation approaches have few or no undesirable impacts, bioenergy is noted as having high risks of negative impacts. These include concerns related to 12 aspects of Nature’s Contributions to People and 5 Sustainable Development Goals. The IPCC notes that here is high confidence in the high technical mitigation potential for bioenergy, but very high confidence that this is constrained by limits including competition for land. They also note that “large areas of monoculture bioenergy crops that displace other land uses can exacerbate these challenges [land degradation, water scarcity, biodiversity loss, food insecurity], while integration into sustainable managed agricultural landscapes can ameliorate them.”

**Methods**

The biomass integration model is an Excel spreadsheet that imports data from sectors that impact production and utilization of biomass, to determine the availability and allocation of biomass feedstocks for mitigation solutions from 2020-2050. Data on adoption and yields from solutions in the Ecosystem Protection and Restoration, Agriculture, and Oceans sectors is used to determine available biomass in six categories. Desired feedstock target amounts are imported from solutions that use biomass in the Electricity, Buildings, Industry, Transportation, and Engineered Sinks sectors. Projected baseline demand and production are compared for all six categories, and surpluses or deficits are determined. Surplus biomass is allocated to solutions based on desired quantities and feedstock suitability. See Figure 1.

In all cases the model results are applied on a year-by year basis from 2020-2050. Results are calculated for a reference (business as usual) scenario as well as for Scenario 1 (roughly 2˚C warming) and Scenario 2 (roughly 1.5˚C warming).

Figure 1: Biomass Integration Model Structure A screenshot of a cell phone

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***Biomass Categories and Suitability***

The Biomass model divides biomass into six categories: sawlogs, other woody biomass, herbaceous biomass, marine algae, cork, and hemp (see Table 2). Not all biomass feedstock types can be used for all applications. Table 3 shows the end-use suitability of biomass feedstock types. In some cases a feedstock type may be technically suitable but not economically wise: for example, sawlogs are best used for timber but could technically be burned as fuel or used for paper. In these cases the model assumes that these feedstocks will not be used for lower-ranked uses. The model does not consider marine algae suitable for uses that require it to be dried first as this is energy-intensive.

Table 2: Biomass feedstock type definitions

|  |  |
| --- | --- |
| **Biomass Feedstock Type** | **Definition** |
| Sawlogs | Whole sections of tree trunk used for the production of sawnwood (lumber for building) and veneers. |
| Other woody biomass | All other lignocellulosic woody plant biomass including pulpwood, fuelwood, other industrial roundwood, and bamboo. |
| Herbaceous biomass | Biomass from herbaceous (non-woody) plants, including dedicated biomass grasses and in-field crop residues like maize stalks and wheat and rice straw. |
| Marine algae | Seaweed or marine macroalgae, produced from ocean farming. |
| Cork | The sustainably harvested inner bark of the tree *Quercus suber*. |
| Hemp | The stem fiber of the annual crop *Cannabis sativa.* |

Table 3: Biomass feedstock type end-use suitability

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **End Use** | **Sawlogs** | **Other woody biomass** | **Herbaceous biomass** | **Marine algae** | **Cork** | **Hemp** |
| Sawnwood | Yes | No | No | No | No | No |
| Building with wood | Yes | No | No | No | No | No |
| Wood-based panels | No | Yes | No | No | No | No |
| Insulation | No | Yes | Yes | No | Yes | Yes |
| Paper & cardboard | No | Yes | Yes | No | No | Yes |
| Cellulosic bioplastic | No | Yes | Yes | Yes | No | Yes |
| Small-scale biogas | No | No | Yes | Yes | No | No |
| 2nd generation biofuel | No | Yes | Yes | Yes | No | Yes |
| Woodfuel | No | Yes | No | No | No | No |
| Biochar | No | Yes | Yes | No | No | Yes |
| Biomass electricity | No | Yes | Yes | No | No | Yes |
| District heating | No | Yes | Yes | No | No | No |

Different production systems (e.g. forest, silvopasture, bamboo) produce different feedstock types. Table 4 shows the biomass products generated by Drawdown’s biomass production systems.

Table 4: Biomass production systems and the feedstock types they produce

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Sawlogs** | **Other woody biomass** | **Herbaceous biomass** | **Marine algae** | **Cork** | **Hemp** |
| Forestry | Yes | Yes |  |  |  |  |
| Dedicated perennial biomass crops | Yes | Yes | Yes |  |  |  |
| Biomass crop on land freed by intensification | Yes | Yes | Yes |  |  | Yes |
| Crop residues |  | Yes | Yes |  |  |  |
| Agroforestry | Yes | Yes |  |  | Yes |  |
| Oceans |  |  |  | Yes |  |  |

***Projected Demand***

Projected demand for sawlogs and other woody biomass is based on historic data from FAO Statistical Service, FAO (2009), and WWF (2012). Demand for herbaceous biomass is assumed to be zero, however the model retains 49% of crop residues in field to maintain soil carbon levels (based on meta-analysis of data points from Lorenz and Lal 2018 and Daioglau 2016), and 25% are already in use (Diaoglou 2016). Marine algae demand is projected forward from FAO (2018). Cork demand is assumed to hold steady at 0.6 MMT/yr. This is calculated using production area and yield data from APCOR (nd), Pereira (2007), and Sierra-Perez (2014). Hemp demand assumes that current demand is essentially zero.

***Demand Reduction***

Three solutions reduce biomass demand: *recycled paper, biogas for cooking* and *improved clean cookstoves.* Both solutions are assumed to use other woody biomass as their primary feedstock (in the form of pulpwood and wood fuel respectively). From each solution model is imported a savings factor of million metric tons of other woody biomass saved for each adoption unit. Adoption data for each is imported from the respective solution models, and the imported savings conversion factor is used to determine the total demand reduction per year from 2020-2050. Note that *biogas for cooking* reduces demand for other woody biomass but increases demand for herbaceous biomass and marine algae.

***Biomass Production***

Biomass production is modeled from six areas: forests, dedicated perennial biomass crops, biomass crops on cropland made available due to intensification, crop residues, agroforestry systems, and oceans. In each case the total MMT of sawlogs, other woody biomass, herbaceous biomass, cork, hemp, and marine algae is calculated.

*Forests*

The model determines the total area of conventional forestry in million hectares by subtracting adoption of forest protection solutions from the total global logged forest area. These forest protection solutions include *forest protection, peatland protection, coastal wetlands protection,* and *Indigenous People’s forest tenure.* Note that in the case of peatland protection, a determination of the percent of peatlands that is forested is based on data from Leifeld (2018). For *coastal wetlands,* only the portion that relates to mangroves is used (excluding seagrass beds and saltmarshes). As the adoption of these practices increases over time, the total area of conventional forestry is gradually reduced. Standard biomass yield of 0.29 t/ha/yr for conventional forestry is based on harvestable mean increment data from FAO (2015). The percent of forest biomass harvest (50.1%) that is sawlogs as opposed to other woody biomass is set using meta-analysis of 13 data points. Yields of sawlogs (0.14 t/ha/yr) and other woody biomass (0.14 t/ha/yr) are set by multiplying the harvestable mean increment by the percent of sawlogs or other woody biomass respectively. The Indigenous People’s forest tenure solution allows the user to set a percentage of the area that is logged. For this study it is set at 100%, thus all of this land is assumed to be harvested. Harvest rates are set at half of those of conventional forestry. The area in conventional forestry decreases steadily over time. Total global yields of sawlogs and other woody biomass are calculated.

*Dedicated Perennial Biomass Crops*

Adoption in Mha *for tree plantations, bamboo production*, and *perennial biomass* are imported from their solution models. Yields from *tree plantations* are based on meta-analysis of 75 data points, and are set at 6.2 t/ha/yr. Yields from *bamboo production* are based on meta-analysis of 21 data points, with a mean of 19.0 t/ha/yr. Of this, 30% is dry weight, based on Kuehl (2015). Yields from *perennial biomass*, including giant grasses and short-rotation woody crops, are based on meta-analysis of 51 data points, and are set at 17.4 t/ha/yr. Mha in adoption is multiplied by yield per hectare to determine global production of biomass in the form of sawlogs (*tree plantations*), other woody biomass (*tree plantations*, *bamboo production*, and *perennial biomass*), and herbaceous biomass (*perennial biomass*). The percentage of *tree plantations* that are sawlog-focused rather than producing other woody biomass only (eg pulpwood plantations) is set by the user. For this study it is set at 55%. Total global yields of sawlogs, other woody biomass, and herbaceous biomass are calculated.

*Biomass from Land Freed Up by Sustainable Intensification*

The model assumes adoption of sustainable intensification of crop yields, through crop diversification and integrated pest management. These yields gains independent of those modeled in the Food Supply Model. These gains allow some cropland to be freed up from food production and made available for other purposes. This newly available area is imported from the sustainable intensification model for the *conservation agriculture, regenerative agriculture, farmland restoration, improved rice,* and *SRI* solution models. The total Mha of freed up cropland is calculated.

The model permits allocation of this cropland made available via yield gains. It can be allocated to *tree plantations* (both for sawlogs and pulpwood), *bamboo production, perennial biomass* (both short rotation coppice for woody biomass and biomass grasses for herbaceous biomass), *forest restoration,* and hemp production. For this study it is set at 35% tree plantations for sawlogs, 50% forest restoration, and 15% hemp.

The model calculates the Mha available for each biomass production approach (and for *forest restoration*, which assumes full protection and no harvest). Yields are calculated as for dedicated perennial biomass crops above. For hemp production, fiber yields of 2.4 t/ha/yr are based on meta-analysis of 11 data points from 5 sources. Total global yields of sawlogs, other woody biomass, herbaceous biomass, and hemp are calculated. The additional area of forest restoration is calculated for use in the *tropical forests* and *temperate forests* solution models.

*Crop Residues*

Total world cropland area is imported from the Land Allocation integration model. Mha of additional cropland is imported from the *abandoned farmland restoration* solution model and added to the total. Cropland no longer in crop production due to sustainable intensification is subtracted from the total. This provides a total global cropland area. This is further divided into perennial and annual cropland as their residue yields and biomass feedstock types are different. Perennial cropland is determined using data from FAO Statistical service, along with adoption data from the *multistrata agroforestry* and *perennial staple crops* solution models. Total Mha of annual and perennial cropland is calculated for each year for each scenario.

The yield of residues from annual crops is calculated for the 20 most widely-grown annual crops based on yield data from FAO Statistical Service and straw to grain ratios from Lal (2005). A global mean of 4.2 t/ha/yr is based on a weighting of the Mha in each crop is calculated. The total area in annual crops is multiplied by this yield to provide a global production of residues in MMT. It is assumed that 25% of crop residues is already in use for livestock feed and other purposes (from Diaoglou 2016). The percentage of crop residues that must remain in the field to conserve soil organic carbon (48.7%) is based on meta-analysis of 7 data points from 2 sources. This percentage is removed from global residue yields as well. The remainder is available for use as herbaceous biomass feedstock.

Perennial crops provide two types of in-field residues: prunings and end-of life. At present most are burned in the field (REF), but they represent a substantial source of other woody biomass. Yields of prunings are set at 4.2 t/ha/yr based on meta-analysis of 10 data points from 2 sources. End of life biomass is set at 2.0 t/ha/yr, based on 8 data points from Lasco (2006), dividing tons/ha at end of life by crop lifespan to produce a mean yield in t/ha/yr. The same percentages of existing use and amount that must be left in field to preserve soil carbon that are calculated for annual crops are applied here as well. The remainder is available for use as other woody biomass feedstock.

*Agroforestry*

Agroforestry system adoptions are imported from the *tree intercropping, silvopasture,* and *multistrata agroforestry* solution models. Each of these approaches contain a diversity of production systems.

For *tree intercropping,* Wolz (2018) was used to determine primary function of woody plants in these agroforestry systems, including biomass, food, fodder, facilitator, and sap, foe tropical, subtropical, and temperate/boreal climates. A percentage of global tree intercropping land in each woody plant role was determined. Mean yields for each production system were calculated using meta-analysis of 57 data points from 29 sources. A weighted global average yield of sawlogs (0.4 t/ha/yr) and other woody biomass (2.4 t/ha/yr) for *tree intercropping* was calculated. This is multipled by the Mha in adoption to provide global production.

For *silvopasture*, Detlefsen and Sommariba (2015) was used to determine the primary function of woody plants in silvopastoral systems. Timber, fodder, and “other” are the functions. It was assumed that no biomass is harvested from “other” silvopasture systems, with shade for livestock as the primary function. Meta-analysis of 29 data points from 5 sources provided mean biomass yields for timber and fodder silvopasture systems. A weighted global average yield of sawlogs (0.4 t/ha/yr) and other woody biomass (3.5 t/ha/yr) for *silvopasture* was calculated. This is multiplied by the Mha in adoption to provide global production.

Iberian *dehesa* and *montado* silvopasture systems are also the primary source of global cork production (Sierra-Perez 2014). Mha in cork production was based on meta-analysis of 3 data points from 3 sources, and cork yields of 0.3 t/ha/yr were based on meta-analysis of 11 data points from 2 sources. Cork is harvested on long rotations, often once every 18 years (Pereira 2007), so all yields are converted to t/ha/yr. The percentage of global silvopasture area that is in cork production is determined by dividing current cork production area over total global silvopasture area. This percentage is assumed to hold steady as silvopasture adoption increases, providing a modest increase in global cork production. Thus *silvopasture* provides sawlogs, other woody biomass, and cork.

In the case of *multistrata agroforestry*, primary functions of woody crop components (biomass, food fodder, facilitator, sap) was based on Wolz (2018). Meta-analysis of 53 data points from 7 sources provided mean biomass yields for these woody plant functions. A weighted global average yield of sawlogs (2.3 t/ha/yr) and other woody biomass (5.4 t/ha/yr) for *multistrata agroforestry* was calculated, and multiplied by Mha in adoption to determine global production.

*Oceans*

Drawdown does not yet have a full solution model for marine algae production (seaweed farming), but basic projections are made here. In Scenario 1, increased adoption is based on the 2005-2015 growth rate of Malaysia, while in Scenario 2 is it based on the 2005-2015 growth rate of Indonesia (growth rates from FAO 2018). Yields of 47.5 t/ha/yr are based on meta-analysis of 8 data points from 3 sources. Mha adoption and per-hectare yields are used to calculate global production for each year.

***Determination of Surplus or Deficit and Allocation***

For each biomass class, total demand, demand reduction, and production is calculated. The model permits allocation of surplus biomass as feedstock for solutions (*biochar, biomass power, bioplastic*, 2nd generation biofuels, building with wood, *insulation, biogas for cooking*, and *district heating*) on a year-by year basis. Because the biomass production system used can greatly impact the carbon payback period for solutions that burn biomass (REF), this information is tracked in the model. For each year, specific production systems can be allocated to specific end uses.

*Sawnwood*

As no sawnwood demand reduction solutions are modeled, baseline demand is used. Total global sawlog production from forestry, dedicated biomass production, land freed up by intensification, and agroforestry is calculated. Data from FAO (2016) is used to set a rate of 43.2% of each sawlog that becomes sawnwood. The remainder becomes wood waste and is accounted for in the Drawdown waste model. For this study all surplus sawnwood is allocated to *building with wood.*

*Other Woody Biomass*

Baseline other woody biomass demand is adjusted due to demand reduction from *recycled paper* and *biogas for cooking.* Total global other woody biomass production from forestry, dedicated biomass production, land freed up by intensification, crop residues, and agroforestry is calculated. For woody crop residues, the percent that is utilized can be set year-by-year, as it is assumed that very little is in use as a feedstock at present. Surpluses are calculated, and a 10% transport loss is assumed, with remainder serving as available surplus. For each solution that uses other woody biomass as a feedstock, the percentage of each production system can be set on a year-by-year basis. Surpluses are allocated to *biochar, biogas for cooking, biomass power, bioplastic, 2nd generation biofuels,* and *district heating.*

*Herbaceous Biomass*

As no herbaceous biomass demand reduction solutions are modeled, baseline demand is used.Total global herbaceous biomass production from dedicated biomass production, land freed up by intensification, and crop residues is calculated. Surpluses are calculated, and a 10% transport loss is assumed, with remainder serving as available surplus. For each solution that uses other woody biomass as a feedstock, the percentage of each production system can be set on a year-by-year basis. Surpluses are allocated to *biochar, biomass power, bioplastic, 2nd generation biofuels, insulation, biogas for cooking* and *district heating.*

*Cork*

As no cork demand reduction solutions are modeled, baseline demand is used. All available surplus is allocated to *insulation*, which is the only Drawdown solution that uses cork as a feedstock.

*Hemp*

As no hemp demand reduction solutions are modeled, baseline demand is used. All available surplus is allocated to *insulation*, which is the only Drawdown solution that uses cork as a feedstock. The model only tracks additional hemp grown on land freed up by intensification, assuming the all other hemp demand is met on existing cropland.

*Marine Algae*

As no marine algae demand reduction solutions are modeled, baseline demand is used. Allocation of surplus marine algae to livestock feed can be set for each year (marine algae have been shown in multiple studies to reduce enteric methane production in ruminants, REF). In this study it is set at 50% for all years. The remainder constitutes the available surplus for Drawdown solutions. For each solution that uses other woody biomass as a feedstock, the percentage of each production system can be set on a year-by-year basis. Surpluses are allocated to *bioplastic, 2nd generation biofuels,* and *biogas for cooking.*

***Total Available Biomass***

For each solution, the total available biomass from each feedstock type and production system is calculated on a year-by-year basis for all scenarios. Allocations can be adjusted to ensure that the requested demand can be met for each solution.

**Results**

***Demand Reduction***

Other woody biomass is the only biomass type for which demand reduction solutions are available. These demand reduction solutions are *biogas for cooking, improved clean cookstoves,* and *paper recycling.* Demand reduction impacts are shown in Figure 2.

Figure 2: Other woody biomass demand reduction MMT/yr in 2050

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***Biomass Production***

*Sawlogs*

Dedicated perennial biomass crop are the largest source of sawlogs in 2050 in all scenarios. Production from forests declines over time, while biomass from agroforestry and land freed up by intensification increases. See Figure X.

Figure 3: Sawlog production by production system 2050 MMT/yr in 2050

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*Other woody biomass*

Dedicated perennial biomass crops are the largest source of other woody biomass in 2050, followed by agroforestry. See Figure X.

Figure 4: Other woody biomass production by production system 2050 MMT/yr in 2050

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*Herbaceous biomass*

Crop residues are the most important source of herbaceous biomass in all scenarios. See Figure X.

Figure 5: Herbaceous biomass production by production system MMT/yr in 2050

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*Cork, hemp, and marine algae*

Cork, hemp, and marine algae each have only one production system in this model. See Figure X.

Figure 6: Cork, hemp, and marine algae production MMT/yr in 2050

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***Surplus Allocation***

Figures X through X show the allocation of biomass feedstock types to meet baseline demand and to solutions that require biomass as a feedstock.

Figure 7: Sawlog allocation MMT/yr in 2050

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Figure 8: Other woody biomass allocation MMT/yr in 2050

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Figure 9: Herbaceous biomass allocation MMT/yr in 2050

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Figure 10: Marine algae allocation MMT/yr in 2050

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Figure 11: Hemp allocation MMT/yr in 2050

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Figure 12: Cork allocation MMT/yr in 2050

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**Discussion**

In both scenarios, biomass production is sufficient to meet the demand for feedstocks for mitigation solutions. This is despite the increase in forest protection which decreases biomass harvest from forest. Overall supply nonetheless increases. Demand reduction is a key component of achieving this goal. The other components are agroforestry and dedicated perennial biomass crops on anthropogenic grassland and cropland freed by intensification.

An advantage of Drawdown’s approach is that land use and adoption of biomass-producing practices is based on the Land Allocation model. This provides a more realistic accounting of land use and feedstock availability than models which use simpler assumptions. As a result biomass emerges as a constraint to the adoption and mitigation impact of 8 solutions. It should be noted that the Drawdown approach does not include any BioEnergy Carbon Capture and Storage (BECCS), which would require greatly increased additional feedstocks (IPCC 2019 *Climate Change and Land* Chapter 6).

Several biomass sources emerged as notable. Residues from woody crops, including prunings and end of life, are mostly burned in the field at present but show impressive potential to provide other woody biomass. Agroforestry systems are underappreciated at present and are a key component to meeting mitigation demand for 2050.

Piotrowski (2015) calculates total wood production at 2100-9400 MMT/yr in 2050, while the Biomass model calculates 6370-8180 MMT/yr of wood in 2050. Piotrowski calculates 1400-5100 MMT/yr of crop residues in 2050, while the Biomass model calculates 4497-4677 MMT/yr of residues in 2050. (IPCC 2019 *Climate Change and Land* Summary for Policymakers) notes a sustainable potential of 200-600 Mha for dedicated perennial biomass crops. Drawdown’s solution models and Land Allocation integration model calculate total adoption of 619-868 Mha. (IPCC 2019 *Land and Climate Change* Chapter 2) notes the technical potential of bioenergy as 100-300 EJ by 2050. The Biomass Model calculates 56-74 EJ in 2050.

Future editions of the Biomass model could break out additional biomass categories, like bamboo. Additional detail like the transport and processing losses could be more thoroughly incorporated as well.

**References**

**~~VMA FORESTS~~**

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**Supplemental Materials**