**THE FOOD SYSTEM MODEL**

*The Drawdown Food System model is designed to understand the impacts of two Drawdown solutions: plant-rich diet and reduced food waste. Running this ‘combined’ model will present results for both solutions implemented individually AND their combined impact when implemented together, including the appropriate allocation of emissions savings to each solution. The “Process” document is a guide to (1) understanding the several spreadsheets that together comprise the Food System model, and aims to provide the instructions necessary to (2) run, and (3) update the model as necessary in the future. The complementary “Methods” document is intended to explain the assumptions and provide the necessary derivations to understand the “Why”s behind the spreadsheets’ technical decisions. These two documents along with the intra-spreadsheet comments and notations, are intended to provide sufficient guidance to future fellows and analysts working with the Food System analysis—but it is complicated, so one shouldn’t hesitate to ask questions.*

**Food System data sources**

FAO + UN

* Food Balance Sheets/Food Supply
  + A list of 10,713 unique country/FAO food commodity pairs are the core, consistent database structure that run through the 2.0 model and ensure the updated, integrated model’s flexibility in generating results that can be summarized by country and/or commodity at any step of the modeling process. This is a shorter list than the 15,000+ used in previous models, but contains all the same data (with many zero-values eliminated) and reduces computation time.
  + This list of unique country/commodity combinations was generated via the following approach (data in the “full country-food list” spreadsheet)
    - FAO supply balance tables from 2010-2013 are merged into a single table
    - Entries with ‘zero’ values in the supply column are sorted out
    - Duplicate country-commodity entries are deleted, irrespective of year, resulting in a comprehensive “country-commodity” list
    - A small list of additional entries were later re-introduced—discussed in detail in the **Plant-rich diet** section
* Food waste estimates
* Alexandratos growth factors
* World Population Prospects
  + Population estimates are included for (and “Current” status assigned for modeling purposes to) the former Sudan (as “Sudan (former)”), because no comparable data are yet available for contemporary Sudan and South Sudan

LCA

* Tilman & Clark; Heller & Keolian; Vieux et al.; Hoolohan et al.; Audsley et al.
* A few modifications were made in the development of the 2.0 integrated model, which modify previously documented methods:
  + Several ‘oils’ were miscategorized as “oil crops” rather than “oils” when assigning LCA impact factors from Tilman & Clark. Oils carry significantly higher impact factors (~2x with ‘min’ emission factors; ~3x with ‘avg’ factors; and nearly 7x with ‘max’ factors).
  + “Rape and mustardseed” and “Palm kernels” were added to the FAO commodity list and assigned “oil crop” emission factors from Tilman & Clark.
  + The emissions factor for “Vegetables, Other” was updated to reflect the appropriate category from Tilman & Clark, which has a material impact on the total system emissions due to significant supply/demand in this category.

Diet

* Bajzelj et al.

**REF supply, waste, and demand**

Food supply, waste, and demand in the reference scenario are based on the most recent comprehensive food supply data available and a recent global food demand forecast (Alexandratos et al. 2012). The original forecast applies only through 2050; in this analysis, we assume that trends from 2030-2050 continue through the following decade—that is, until 2060.

In this revised, integrated Food System model, the food demand forecast drives waste estimates and therefore supply estimates—as opposed to the original plant-rich diet and food waste models, which forecasted supply first, then derived waste based on those figures. By implication, we are assuming that global food demand is the ultimate driver of food production and agricultural land use trends within the Food System.

However, the available baseline data provided by FAO is for supply rather than demand (i.e., consumption), and only runs through 2013 (as of January 2019). Further complicating things, FAO data specifically represent the amount of food supplied or ‘made available’ to consumers at the retail level. Adjustments are made early in the modeling process to account for this quirk of the data, to ensure that model assumptions and parameters relating to consumption, emissions, and waste are applied appropriately.

The Food System model begins in the ***FOOD inputs*** spreadsheet by adjusting raw ‘supply’ data from the FAO—which reflects the volume of food supplied to consumers—to instead reflect food supply at the farm-gate, i.e. as it leaves the farm and enters the downstream supply chain (See Fig. 1).

In the Drawdown Food System model framework, Demand is what remains after all losses and waste is accounted for, starting with the theoretical maximum supply. Using the shorthand from Fig. 1:

*Sm = D + Wc + Ws + Wp*

The LCA factors used in the model provide per-kcal emissions estimates *based on the amount of food leaving the farm-gate*. For this reason, “Supply” (S) in the model specifically refers to supply *at the farm gate* (“Waste” in the model refers to the sum ‘Wc + Ws’, or the total amount of food lost/wasted—i.e., not consumed—post–farm gate). Since this is the value we use in the model, we can isolate Supply in the framework, again using shorthand from Fig. 1:

*Supply = D + Wc + Ws = Sp + Ws*

We can therefore apply the model’s waste factors to the FAO data (Sp) in order back out upstream Supply values. The total amount of supply chain waste (Ws) can be calculated as a function of Supply using the pre-consumption, post–farm gate food loss rate (Ws’). The pre-consumption, post–farm gate food loss rate is derived by applying food loss rates from all included waste life-cycle stages:

*Ws’ = (1 – food handling and storage loss rate)\*(1 – processing loss rate)\*(1 – packaging loss rate)\*(1 – distribution loss rate)*

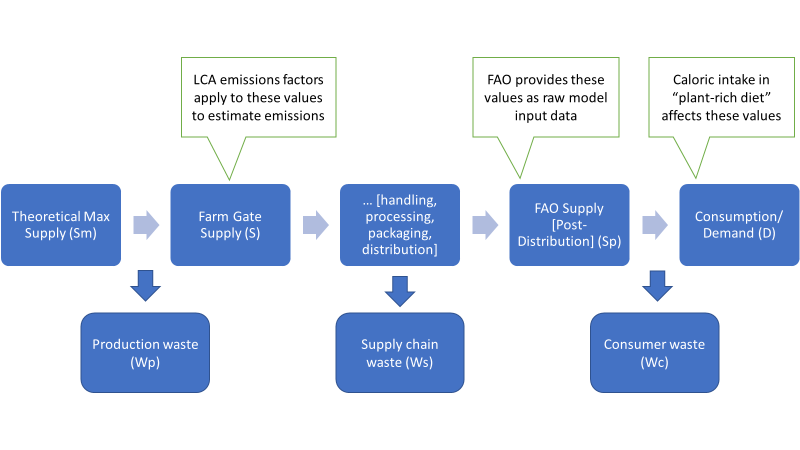
Supply chain waste can be calculated as:

*Ws = Supply\*Ws’*

The final calculation for Supply is therefore derived as follows, where the quantity (1-Ws’) represents the percentage of farm gate supply that ultimately reaches the consumer:

*Supply = Sp + Supply\*Ws’*

*Supply = Sp/(1-Ws’)*



*Fig. 1: Supply and waste flows in Food System model framework*

The model then estimates supply in 2014 for each FAO commodity in each country, forecasting growth into the model’s first year (2015):

*Food supply(2014) = AVG(FAO\_supply[2011:2013])*

*REF\_supply(2015) = Food supply(2014) \* (1 +* Alexandratos growth factor [Ag])

Supply is then converted to waste using the post–farm gate food loss rate by waste category and waste region (Wf), which is assumed to be constant in the REF case:

*REF\_waste(2015) = REF\_supply(2015)\*Wf*

NB: The source of food loss rate data does not provide estimates for all foods; those not covered explicitly are grouped together under an “Other” waste category. To calculate post–farm gate food loss rates for this “Other” category, the waste system model is run, for all other waste categories through to its end in order to generate waste mass by food life cycle stage. Using these final waste mass values, the “Other” post–farm gate food loss rates are estimated as the total waste by region divided by the total supply by region.

These two values (waste and supply) are then converted to demand, which can be thought of as the portion of food supply that is not wasted. In other words:

*REF\_demand(2015) = REF\_supply(2015) - REF\_waste(2015)*

With this first year’s demand defined, the process order flips, and demand becomes the baseline. We express demand in a given year (from 2016-2060) as a function of the previous year’s demand (rather than as an exponential function of time since 2015), because Ag factors are different stepwise from 2015-2030, and from 2030-2060:

*REF\_demand(Year) = REF\_demand(Year - 1) \* (1 + Ag)*

Because of the simple algebraic relationship between demand, waste, and supply, we can express waste as a function of only demand and the post–farm gate loss rate (Wf):

*Demand + Waste = Supply; Waste = Supply \* Wf*

*Demand + Waste = Waste/Wf*

*Waste/Wf - Waste = Demand*

*(Waste - Waste\*Wf)/Wf = Demand*

*Waste \* (1-Wf)/Wf = Demand*

*Waste = Demand \* Wf/(1-Wf)*

The REF waste forecast for each year from 2016-2060 is thus generated according to the equation:

*REF\_waste = REF\_demand \* Wf/(1-Wf)*

The REF supply forecast for each year from 2016-2060 is then completed by taking the sum of demand and waste:

*REF\_supply = REF\_demand + REF\_waste*

**Plant-rich demand**

Plant-rich demand is generated on a per-capita basis, as are the REF forecasts, and can be conceptualized as the “average diet of each person who adopts a plant-rich diet”. This is also best conceptualized a model input, not a forecast per se, since its purpose is to feed into the PDS demand forecast rather than to represent—as it, technically, does—what food demand consumption would look like if 100 percent of people adopted a plant-rich diet starting in 2015.

The ‘plant-rich diet’ as modeled here in the ***FOOD inputs*** spreadsheet is a combination of (A) the “healthy” diet as conceived by Bajzelj et al. (2014) for various food groups (‘diet categories’), (B) the assumed total caloric demand (a key input parameter in the Food System model), and (C) the estimated balance of demand across FAO commodities in each given year.

(C) is used to allocate demand among FAO commodities within the diet categories from Bajzelj et al. on the basis of relative forecasted demand among those FAO commodities. This is expressed in a ‘relative demand factor’ (Df), expressing the percentage of diet category calories comprised of each given FAO commodity. For each FAO commodity, in a given country, in a given year:

*Df = REF\_demand(commodity, country, year)/SUM over diet category{REF\_demand(diet category, country, year)}*

This factor is multiplied by the ‘healthy’ diet demand from Bajzelj et al., then normalized to total calories in the plant-rich diet (Ci), to yield the plant-rich demand for each FAO commodity, in each country, in each year:

*Plantrich\_demand = Df(FAO commodity, country, year) \* ‘Healthy’ demand(diet region, diet category)\*Ci/ SUM{‘healthy’ diet calories in given region}*

As long as the total daily caloric consumption input parameter for plant-rich diet is set to 2500 or less, this approach conforms with the Bajzelj et al. framework’s “maximum” limits on the consumption of certain commodity groups, for example including beef and vegetable oils. If that total daily caloric consumption input value is less than 2500 calories, however, then the resulting caloric demands for commodity groups at or near the Bajzelj et al. framework’s “minimum” limits will fall below those limits. This analysis therefore implicitly assumes that these “minimum” floors are designed to assign a minimum *relative* concentration of fruits and vegetables in individuals’ diet, rather than a minimum *absolute* concentration. This assumption should be revisited if/when the dietary model is improved in the future (perhaps also to update assumptions about minimum protein requirements, for example), as it does not appear to be in keeping with Bajzelj et al.’s intent.

NB: in the first draft of the v2 model, a short list of countries were under-assigned calories in their plant-rich diets due to those countries not having a baseline demand for FAO commodities in a given diet category. Without a baseline REF\_demand (e.g., zero “maize” demand in 2011-2013), in the above formulae “Df” would be zero, and thus that category would be assigned zero calories and the total calories in the resulting plant-rich diet would be less than the target value set in the scenario parameters. This was addressed by:

1. Creating new entries in the core database for several unique country-commodity pairs, increasing the total number of entries from 10,687 to 10,713. Countries had been identified as missing foods from a given “diet category”—not specific FAO commodities. Rather than assuming an arbitrary distribution of commodities, discretion was used to choose single FAO commodities in each ‘missing’ category for each affected country. Commodities were chosen to be as general as possible—“Pulses, Other and products” for the pulses category; “Maize and products” for the maize category; “Marine Fish, Other” for the fish category; and “Cereals, Other” for the other grains category.
2. Each of these added country-commodity pairs—and two others, which were already in the database but with zero-values—are then assigned very low supply (and therefore waste and demand) values of 0.001 kcal/cap-day in 2015. This low value is chosen to ensure that their impact on the REF forecast is negligible—though in the above formulae any non-zero value will have a larger impact on the final plant-rich diets in the affected countries.

An alternative approach would have been to merely assign the ‘missing’ calories in proportion to all existing food commodities. This approach may be slightly more complex to implement, but is worthy of consideration in future model iterations.

**Adoption**

Starting in the ***CORE*** spreadsheet, attention shifts to the Project Drawdown Scenario (PDS) forecasts, which are driven by the adoption assumptions for both plant-rich diet and food waste. Adoption for both solutions grows linearly, starting in the first year of adoption and with adoption reaching its target value in the final year. Both the first and final year of adoption are separate input parameters for each solution. So, for each solution, we have adoption as a function of the current year (Y), adoption start year (Yo), and adoption completion year (Yf):

*Adoption rate (A) = A\*(Y-Yo+1)/(Yf-Yo+1)*

This function is designed to have the properties that in Yf, adoption = A; in year (Yo - 1), adoption is zero, and that in the intermediate years adoption grows linearly. If the start year is later than 2015, adoption is assumed to be zero until the first year; if the completion year is earlier than 2060, then adoption rate is held constant (at A) for the remainder of the forecast.

**DIET demand, waste, and supply**

The DIET forecasts for demand, waste, and supply in the ***CORE*** spreadsheet flow from demand forecasts, mirroring the REF forecast methodology starting in 2016. “DIET\_demand” values are constructed based on adoption to-date of the plant-rich diet solution:

*DIET\_demand = Plantrich\_demand \* A + REF\_demand \* (1 - A)*

As in the REF forecast from 2016 onwards, PDS\_waste is simply a function of PDS\_demand and each given year’s waste factor, which remains constant:

*DIET\_waste = DIET\_demand \* Wf/(1-Wf)*

DIET\_supply is simply forecast as the sum of DIET\_demand and DIET\_waste:

*DIET\_supply = DIET\_demand + DIET\_waste*

**WASTE demand, waste, and supply**

The WASTE forecasts for demand, waste, and supply in the ***CORE*** spreadsheet flow from demand forecasts, mirroring the REF forecast methodology starting in 2016. “WASTE\_demand” values are unchanged from the REF case:

*WASTE\_demand = REF\_demand*

As in the REF forecast, WASTE\_waste is simply a function of WASTE\_demand and each given year’s waste factor. In this case, however, the waste factor (Wf) decreases over time as the adoption of the food waste reduction solution increases:

*WASTE\_waste = WASTE\_demand \* Wf/(1-Wf)*

WASTE\_supply is simply forecast as the sum of WASTE\_demand and WASTE\_waste:

*WASTE\_supply = WASTE\_demand + WASTE\_waste*

**PDS demand, waste, and supply**

The Project Drawdown Scenario (PDS) forecasts for demand, waste, and supply in the ***CORE*** spreadsheet flow from demand forecasts, mirroring the REF forecasts starting in 2016. As in the DIET case, “PDS\_demand” values are constructed based on adoption to-date of the plant-rich diet solution:

*PDS\_demand = Plantrich\_demand \* A + REF\_demand \* (1 - A)*

As in the WASTE case, the waste factor (Wf) decreases over time as the adoption of the food waste reduction solution increases:

*PDS\_waste = PDS\_demand \* Wf/(1-Wf)*

PDS\_supply is simply forecast as the sum of PDS\_demand and PDS\_waste:

*PDS\_supply = PDS\_demand + PDS\_waste*

**PDS and REF emissions**

While demand drives waste and supply in the Food System model, emissions—calculated in the ***EMISSIONS and YIELD*** spreadsheet—still result from the total *supply* of food. In the REF case, this is simply expressed as the per-capita, per-day supply multiplied by LCA emissions impact factor for each food commodity, then multiplied by 365 and divided by 10^6 (g/tonne conversion) to generate annual values in tonnes for each given country in a given year. This calculation also applies to the WASTE scenario:

*REF\_emissions =* SUM over all commodities *{REF\_supply \* If \* Pop} \* 365 / 10^6*

Emissions in the PDS case are slightly more complex, because in the modeling framework we have part of the population who is eating the REF case diet (1-A), and another part that is eating the plant-rich diet (A) in any given year. The impact of plant-rich diet also includes a ‘localization factor’ (Lf) that is assumed to reduce emissions by 5 percent across FAO commodities, which is applied as a reduction to the LCA impact factor (If). For this reason, we need to isolate the per-capita supply of plant-rich diet. This is generated by defining plant-rich supply as a function of plant-rich demand (using the same algebra used previously to calculate waste as a function of demand). These calculations also apply to the DIET scenario:

*Demand + Waste = Supply; Waste = Supply\*Wf*

*Supply = Demand + Supply\*Wf*

*Supply \* (1 - Wf) = Demand*

*Supply = Demand/(1 - Wf)*

Since we are only interested in plant-rich supply, we must adjust for adoption:

*Plant-rich\_supply = Plant-rich\_demand\*A/(1-Wf)*

We can then express the total PDS emissions as the sum of emissions from its component parts: plant-rich diet supply for the fraction of people who have ‘adopted’ the solution, and REF diet supply for the fraction who have not, in a given year:

*PDS emissions = [REF\_supply\*If\*Pop\*(1-A) + Plant-rich\_supply\*If\*(1- Lf)\*Pop\*A]\*365/10^6*

**Global food yield**

Global food yield is generated in the ***EMISSIONS and YIELD*** spreadsheet by a simple calculation—summing total global food supply in the REF and PDS scenarios within the food categories used in the Yield model (‘yield categories’).

Yield categories include “Grains” and individual livestock-related categories. “Grain” totals are the sum of the following categories, used in the food waste model: ‘Cereals’, ‘Fruits and Vegetables’, ‘Oilseeds and pulses’, ‘Roots and tubers’, and ‘Other’. The addition of the “Other” category, whey, and fish/seafood entries are changes from the first version of the food system model. Livestock-related yield categories (and fish/seafood entries) reflect the totals of their own individual FAO commodities.

Global yield for each category in each given year is calculated in grams after applying a kcal-to-g conversion factor as:

*Yield = SUM, over all FAO commodities and countries { Supply \* g/kcal \* Pop} \* 365*

NB: the kcal-to-g conversion factor was generated by downloading 2013 Food Supply tables for both kcal/capita/day and g/capita/day and dividing the former by the latter for each FAO commodity. For commodities that either (1) are included in FAO supply tables but with zero supply indicated, or (2) are included in FAO supply tables [generally with only a few countries reporting] but show up in the global average as having zero average caloric demand, the following assumptions have been made:

* *Sugar Beet* is assumed to have an equal caloric density as *Sugar (Raw equivalent)*
* Caloric density values for *Cloves* (“cloves, ground”, in the USDA database), *Pepper* (“pepper, black”), and *Rape and Mustardseed* (“mustardseed, ground”) are taken from the [USDA nutritional database](https://ndb.nal.usda.gov/ndb/search/list), as they are estimated as zero values when derived directly from FAO data, which leads to calculation errors.
* The caloric density value for *Palm Kernels* is assumed to be the average of *Palm Oil* and *Palmkernel Oil*, a decision currently without strong justification but also with limited impact on model results given how small Palm Kernels’ supply is.
* The values for *Molasses*; *Meat, Aquatic Mammals*; *Whey*; and *Roots & Tuber Dry Equiv* are all left as zeros because they all have zero supply in the FAO tables anyway
* The values for *Fish, Body Oil*; and *Fish, Liver Oil* are assumed to contain 9 kcal/g on the basis of being approximately pure fat
* The value for *Aquatic Animals, Others* is calculated as a simple average of the kcal/g factors for: *Cephalopods*; *Crustaceans*; *Demersal Fish*; *Freshwater Fish*; *Marine Fish, Other*; *Molluscs, Other*; and *Pelagic Fish*

The resulting yield forecast values are divided by 10^12 to convert from g to million-metric-tonnes.

**Waste fractions throughout waste cycle**

The total waste in each country could be easily calculated, but for Drawdown’s Waste model it is useful to have more detailed waste totals broken down by food waste category and by life cycle stage in order to allocate the burden of waste disposal to various processes appropriately (“waste” and “loss” are used interchangeably here, though in referenced FAO materials “waste” is only used to refer to avoidable losses at the retail and consumer level).

Since the REF\_waste and PDS\_waste outputs already provide an estimate of total post–farm gate food waste, the task for the ***WASTE*** spreadsheet is to divide that total into distinct food waste categories and according to distinct stages of the food life cycle. The former case is trivial given the model’s structure (since waste is reported by FAO commodity and can thus be easily summarized by category), but the latter requires a bit of groundwork to understand the *percentage of the final waste stream* for which each life-cycle stage accounts.

Waste rate values (Wi) are reported as the “percentage of food lost at each stage of the food life cycle”, by both region and waste category. In the ***WASTE*** spreadsheet, these are converted to “percentage of post–farm gate food supply remaining after each stage of the food life cycle” (Wr)—in other words, if you started with “100 foods” at the farm gate, and 10 percent are lost during the “postharvest handling and storage” phase, then 90 foods would remain as ‘inputs’ to the “processing” phase, so Wr = 90 percent for the “postharvest handling and storage” stage. If another 10 percent are lost during the “packaging” phase, then 81 would remain, and thus Wr = 0.81 for the “packaging” phase. After all losses are accounted for, a post–farm gate loss rate (Wf) of 40 percent would mean that 60 foods would actually be eaten during the final “consumption” stage. For example, for each waste category and region:

*Wr(postharvest handling and storage) = 1-Wi(postharvest handling and storage)*

*Wr(processing) = Wr(postharvest handling and storage)\*[1 – Wi(processing)]*

*Wr(packaging) = Wr(processing)\*[1-Wi(packaging)]*

*… and so forth, with the distribution and consumption stages following, in that order.*

Agricultural production waste/losses are accounted for differently since they occur upstream of the model’s post–farm gate supply. Rather than a percent remaining, they are calculated as a ratio of loss-less supply (or ‘theorerical maximum supply’, Sm) to farm gate supply, which is thus defined as 100 percent for each unique region and waste category combination. So, continuing with the example above, if you have “100 foods” at the farm gate, and the agricultural production loss rate had been 20 percent, then you would estimate the ratio of loss-less supply to farm gate supply as:

*Wr(agricultural production) = Sm/Supply = 1/[1-Wi(agricultural production)]*

This would yield an estimate of 1.25, or 125 percent, suggesting that the theoretical maximum supply is 125 foods, and that 25 are lost during the agricultural production phase.

In order to allocate already-modeled waste estimates to these various life cycle stages—continuing with the same example—we would then want to understand what percentage of the 40 lost foods (post–farm gate waste) were lost during the “postharvest handling and storage” phase—which would be the amount lost in that phase (10) divided by the total lost after the farm gate (40) = 10/40 = 25 percent. More generally, where Wf is the total post–farm gate loss rate for each given region and waste category:

*Waste percent (Wp) = Percentage \*of farm gate supply\* lost in a given life-cycle stage / Wf*

A couple examples:

*Wp(postharvest handling and storage) = [1-Wr(postharvest handling and storage)]/Wf*

*Wp(processing) = [Wr(postharvest handling and storage)-Wr(processing)]/Wf*

*Wp(packaging) = [Wr(processing)-Wr(packaging)]/Wf*

*(and so forth, for the remaining two stages)*

Given our definition of Wr(agricultural production), with a minor tweak this formula applies equally to the calculation of Wp(agricultural production):

*Wp(agricultural production) = [Wr(agricultural production)-1]/Wf*

NB: Because the FAO Global Food Losses source (from which waste rates are derived in the Drawdown model) does not cover all FAO commodities, it was necessary to calculate an averaged, post–farm gate regional loss rate to estimate the Wf factor for “Other” foods (by region). It is similarly necessary to generate regional “Other” waste/loss estimates by life-cycle stage, which was done in the ***Other\_waste\_calculation*** spreadsheet, whose results are then copied and pasted into the ***FOOD Inputs*** spreadsheet.

Waste values given in kcal/(cap-day) values are converted to g/(cap-day) in the ***WASTE*** spreadsheet, to facilitate allocating waste to the various stages of its life cycle on a mass basis.

Life-cycle waste fractions (in tonnes, by country, waste category, life cycle stage, and year) are the sum of all waste (by mass) in a given country and waste category, apportioned into food life-cycle stages by multiplying the total mass of waste by Wp. These values are also converted from grams to tonnes using a factor of 10^6. For each waste category and country, life-cycle waste fraction (Fw) is thus calculated as:

*Fw = SUM over FAO commodities {Waste \* Wp} \* Pop \* 365/10^6*

**Results**

All other tabs, including those found in the final spreadsheet, **Food System RESULTS**, serve merely to summarize data in tables whose data is already described here. These summaries should all be intuitive—e.g., summaries of CO2e emissions by food commodity represent the sum of all CO2e impacts, across all countries, for each FAO commodity.

One piece of analysis worth further discussion, however, is the appropriate allocation of emissions, supply, waste, and yield savings between the diet and food waste solutions when the integrated Food System model is run. The results tabs (characterized by dark green in the **EMISSIONS and YIELD** and **WASTE** spreadsheets, and which are intended to be copied into the **Food System** **RESULTS** spreadsheet) each summarize the Food System model results in terms of (1) the cumulative/combined total impact of both plant-rich diet and reduced food waste solutions, as well as the individual impacts of (2) the plant-rich diet solution and (3) the reduced food waste solution, and finally (4) the impact of the family planning solution when implemented with zero adoption of either plant-rich diet or reduced food waste.

Additionally, within the first of those summaries—the cumulative/combined total impact of plant-rich diet and reduced food waste solutions—the model allocates *relative* impacts (in terms of emissions, yield, supply, and waste savings) to the plant-rich diet and reduced food waste solutions. This is necessary because the sum of impacts (2) and (3) referenced above is not equal to the impact of (1)—that is to say, the individual impacts of each food system solution do not neatly add up to their cumulative impact when implemented in parallel. The reason for this stems from the fact that changing model assumptions about diet has implications for waste volumes as well—so when the plant-rich diet solution is implemented, it alters the amount of waste that is acted on by the reducing food waste solution.

Because the reverse is not true—reducing waste does not reduce the amount of food consumed—the relative impacts of plant-rich diet and reduced food waste [when both solutions are implemented in parallel] are assigned first to plant-rich diet, i.e. plant-rich diet is assumed to mitigate the same volume of greenhouse gas emissions and reduce food supply, waste, and yields by the same tonnage as if it were implemented as a standalone solution. Reduced food waste is assigned the remainder of the cumulative savings.