Reducing food waste by households and in retail in the EU

A prioritisation using economic, land use and food security impacts

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Preface

Food waste is a contentious issue at times where hunger amongst the poor is still prevalent. Given a growing population, pressures from competing claims of feed, food and fuel demands on scarce natural resources of water and land, are only likely to increase. In the EU, adverse economic timings make the need for a more resource-efficient economy all the more pressing.

This report describes the impacts of reducing food waste by households and retail in the EU, given that in the EU, as in other industrialised countries, this is where a lot of the waste occurs and so is prioritised by policymakers. In view of the broader aim of resource efficiency, the outcomes are contrasted with those associated with adopting a healthier diet. All results have been presented as a difference from a baseline scenario, which captures current trends in major socio-economic drivers, so as to be able to isolate the impacts of the proposed scenarios. The time frame of analysis is 2020, the target year for the milestone of halving food waste set by the EU in its 'Roadmap to a Resource-Efficient Europe', which we interpreted as an ambitious target. We also incorporate a more realistic and modest scenario of reducing food waste by, respectively, 40 and 30%. Whether these targets can or will be realised in 2020 depends on many factors and uncertainties. The answer to this question lies beyond the scope of this report.

The analysis was far from easy given the lack of consistent and reliable data for the EU (e.g. with respect to waste data for different commodities at the Member State level, information on costs associated with reducing waste, causes, and household behaviour regarding waste and waste reductions). Despite the various caveats and limitations, this study is able to provide important insights into the answers to the following questions:

1. Which sectors should receive priority when reducing food waste on the demand side (by households and in retail)?
2. How does this compare with pursuing a healthy diet in the EU?

These questions have been answered using indicators that are available in the MAGNET model used to carry out the scenario analysis. These include the indicators of value added generated in the EU economy (GDP), land use in the EU and food security (food consumption and prices) in Sub-Saharan Africa.

We also look into whether, from the perspective of food security in developing regions and given that the prevalence of hunger is often cited as the main

motivation of reducing food waste, these policies are the best policies to focus on.

The analysis, to our knowledge, is the first detailed and applied study on impacts associated with reducing food waste by households and retail in the EU. By providing a structured account of expected impacts - on the demand side (consumers, their diets and food security), the supply side (producers), the labour market, land use, trade patterns and overall GDP - this study is able to reveal the various trade-offs that occur, which adds to the information base for policy-making.

L.C. van Staalduinen MSc
Managing Director LEI Wageningen UR

Summary

S.1 Key findings

1. *Reducing food waste by EU households leads to annual household savings of 92 euro per capita (30% reduction in household waste by 2020), 123 euro per capita (40% reduction by 2020) or 153 euro per capita (50% reduction by 2020). This amounts to an annual saving of 56.6, 75.5 or 94.4 billion euro for the EU in total in the 30%, 40% and 50% waste reduction scenarios respectively. Relative to the average EU-household budget spent on food in 2020 this represents a saving of 5%, 7% or 9% respectively.*

In the absence of knowledge on how the saved expenditures will be used it is assumed that all sectors in the economy (food and non-food) benefit equally from the expenditures freed up from reducing food waste by households. Household welfare thereby increases. The reallocation of household expenditures away from previously wasted foods towards other food and non-food sectors does lead to changes in the economy, with some sectors gaining and some sectors losing (Section 5.10.2). These impacts, which are outcomes of the modelling exercise, are reported below (point 2 to 7) for the realistic scenario (40% reduction in food waste).

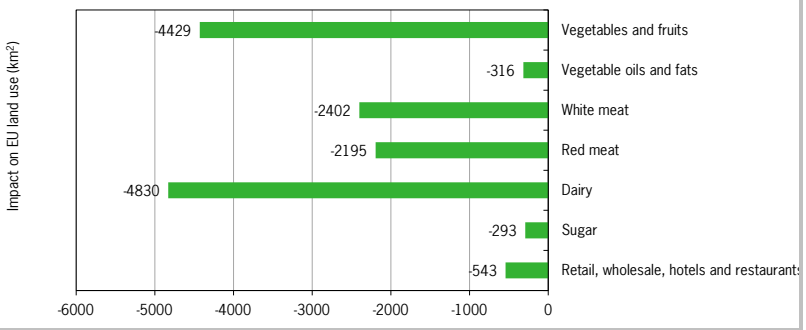
2. *Overall savings in land use of reducing food waste by households and in retail in the EU are considerable, 28,940 km^2 – close to the land area of Belgium (approximately 1.6% of EU agricultural lands in 2020).*

This freed up land could, for example, be used for food production for exports to other countries in the world or biofuel production to satisfy EU energy needs.

3. *The largest contributions to land use savings in the EU are from:*
   i. *dairy products* due to their strong linkages with live animal (cattle producing raw milk) and feed sectors (cereals; Section 5.3.3);
   ii. *vegetables and fruits*, for which household waste is relatively large (Section 5.2.3);
   iii. *red and white meat products*, also with strong linkages to live animal (chicken, pig, cattle) and feed sectors (Sections 5.1.3 and 5.4.3).

Reducing household food waste of dairy products contributes to 17% of the savings in land use, followed by vegetables and fruits (15%), both around twice as much as land use reductions from reducing household waste in white meat (8%) and red meat (8%).

Figure S.1 **Impact on land use in 2020 of reducing household waste for a selection of commodities and of reducing waste in retail in the EU** [a)]



a) Outcomes of the realistic scenario (40% reduction). Agricultural land in the EU is estimated at 1.8m km^2 in 2020. Given that 1 km^2 = 100 ha (hectares), this amounts to 180m ha. Sugar contains raw sugar, molasses and other sweeteners.

4. *Reducing food waste by households and in retail combined leaves the EU economy relatively unaffected (EU GDP in 2020 is 0.09% lower than projected), with the EU recording a baseline GDP growth of approximately 17% over the period of 2012-2020.*

The small minus sign for GDP illustrates that lower food waste by households and in retail entails lower demand for some food commodities to the benefit of other food and non-food commodities, but on net slightly lowering value added generated in the EU economy. GDP, however, is not a good indicator of overall welfare as it does not incorporate the aforementioned welfare gains to consumers.

5. *Sectors that contribute positively to EU GDP include:*
   i. *reducing household waste of vegetables and fruits*;
   ii. *reducing waste in retail* (which in the model includes wholesale, hotels and restaurants).

Reducing household waste of vegetables and fruits, which has a lot of potential as waste is very high for perishables, seems to benefit the EU economy due to increased expenditures on other commodities that generate a higher value added (see Section 5.2.1). Reducing retail waste leads to a decrease in costs and an increase in sales which benefits the rest of the EU economy (see Section 5.7.1).

6. *On average, the impacts of reducing food waste by households and in retail in the EU on food security in Sub-Saharan Africa, whilst positive, are relatively small*

Interestingly, also here the largest contributions stem from EU household waste reductions in vegetables and fruits. These benefits may only be enjoyed by urban households as falling prices may lead to lower incomes for rural households who depend on agriculture for their rural livelihoods. The limited impacts on food security for the average household, especially in Sub-Saharan Africa but also in other developing regions, suggest that, if food security is the prime concern, it is better to focus on other policies, such as policies that improve market access or improve the investment climate in these regions (Section 5.10.2).

7. *The adoption of a healthy diet generally performs better than reducing waste by households and in retail in the EU (Section 5.10.3). The former compared to the latter:*

i. *halves the fall in EU GDP.*

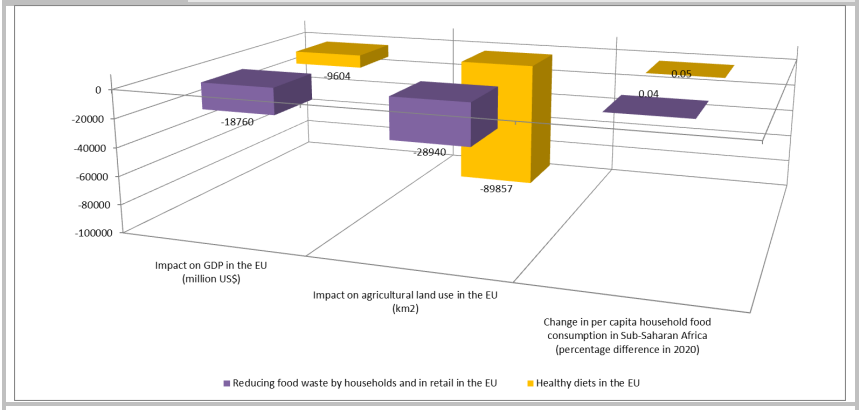
Reducing waste by households and retail negatively affects all agri-food sectors, whereas a targeted reduction in the demand for animal-based products harms associated sectors but benefits other agri-food sectors as households substitute consumption away from animal-based products towards more healthy foods (such as vegetables and fruits, vegetable oils and fats, etc.).

ii. *reduces EU land use threefold.*

Animal-based sectors are relatively more intertwined with the rest of the economy, notably with live animal and feed sectors. As a consequence, the fall in demand - which is also much bigger in the animal-based sectors simply because the healthy diet shocks are relatively large compared with the food waste shocks - results in a larger negative impact on land use.

iii. *seems more effective in increasing food security of the average household in Sub-Saharan Africa, although impacts are very small.*

Figure S.2 **The reduction in household and retail food waste compared with the adoption of a healthy diet in the EU on outcomes in 2020** [a)]



a) Outcomes of reducing EU household and retail food waste in the realistic scenario (40% reduction). GDP is measured in constant 2007 USD. GDP and agricultural land in the EU are estimated at, respectively, USD20 trillion and 1.8m km^2 in 2020 assuming a continuation of current trends and no new policies.

These findings suggest that it is better to accompany waste reductions by households and retail in the EU by a - more durable and sustainable - behavioural change towards a healthy diet. If other industrialised regions take similar actions, the impacts will increase.

S.2 Complementary findings

Reductions in household and retail food waste in total or eating more healthily leads to trade-offs, i.e. there are winners and losers (Section 5.10.1):

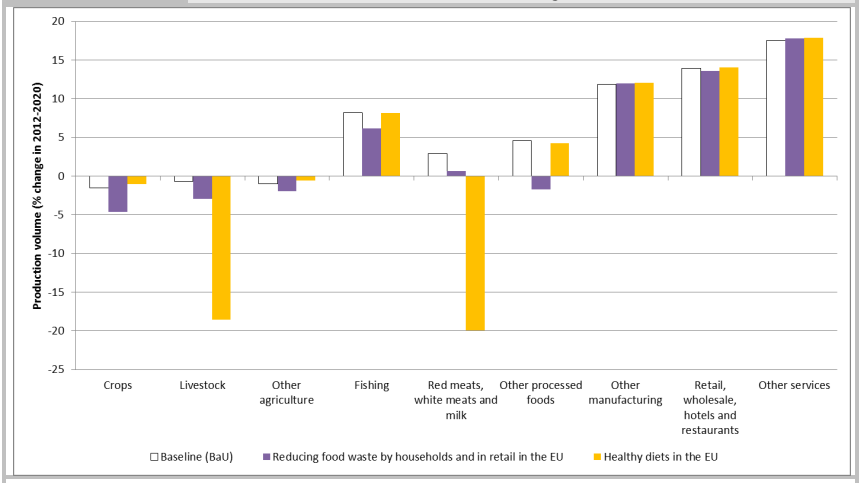
A. *between producers in the EU:*

Resources move out of those sectors that suffer from reduced demand due to lower wastage of food or a healthier diet (animal-based sectors), into other sectors that benefit from increased spending from savings on previously wasted foods or, with respect to healthy diets, savings on animal-based products. Animal-based sectors (dairy, red meat and white meat products) are relatively strongly interlinked with related live animal (cattle, raw milk from milk-producing cows, chicken and pigs) and feed sectors (cereals), so that if the former are negatively impacted due to reductions in household waste or healthier diets, the

latter also will be (see Sections 5.1.2, 5.3.2 and 5.4.2). A similar effect occurs between sugar (including raw sugar, molasses and other sweeteners), and sugar cane and beets sectors (Section 5.5.2). Retail and the 'other food' sector (see Sections 5.7 and 5.6 respectively) are generally more interlinked with all other agri-food sectors and bigger in size which explains why waste reductions here, especially in the 'other food' sector, have a greater impact.

When EU food waste by households as well as retail is reduced for all food commodities, all agri-food sectors contract and see production volumes fall by an average of 4.4% compared to what was projected in 2020 (in the baseline). Resources move out of agri-food sectors into manufacturing and services, which slightly expand.

Figure S.3 **Changes in production volumes in 2012-2020 in the baseline, waste reduction [a] and healthy diet scenarios**



a) Outcomes of reducing EU household and retail food waste in the realistic scenario (40% reduction).

B. *in terms of labour market impacts in the EU:*

Employment and real wages in EU primary agricultural sectors decline whereas employment and real wages in EU manufacturing and services rise.
This merely strengthens the ongoing process of a declining importance of the agricultural sector and increased importance of manufacturing and services in the EU economy. It suggests that additional farm support policies may be necessary to support the agricultural sector during this transition.

C. *between producers and consumers in the EU:*

The latter become better off as their welfare rises from avoiding waste and they benefit in terms of food security:
Ignoring for the moment the issue of diet quality, EU households benefit from lower food prices and increased consumption (excluding waste) of food using savings on previously wasted foods (see Section 5.8.1). The move towards a healthy diet in the EU, however, implies a fall in household consumption of animal-based products in the EU, which outweighs the increase in consumption of other agri-food commodities (see Section 5.9.1). Also, a reduction in waste by retail (including wholesale, hotels and restaurants) in the EU, causes EU households to substitute demand away from agri-food commodities towards relatively cheaper fish, retail and other services and so lowering household food consumption in the EU (see Section 5.7.1).

D. *across policy goals in the EU (see Table 5.1 and Section 5.10.1):*

Aforementioned slight losses in GDP, need to be balanced with gains in consumer welfare and food security, but also with positive impacts in terms of savings in land use, slightly negative impacts in terms of dietary change and an improved trade pattern:

1. *the EU saves more on land use*

Land use in the EU generally changes in line with sectoral developments, with some substitution away from contracting sectors towards expanding sectors (due to a fall in land prices from lower demand for certain agri-food commodities, land demand in other agricultural sectors is observed to increase). However, these secondary effects are relatively small so that overall land use always declines.

2. *due to lower EU food waste, diets in the EU generally become slightly less healthy, as measured by the share of animal-based products in the consumption basket of households*

Savings freed up from reducing waste are spent a little more on more 'luxurious' commodities, including animal-based products, i.e. EU consumers are observed to 'trade up' their consumption pattern. Impacts are small as savings on food expenditures are spread out over the prevailing consumption basket.

3. *EU trade patterns generally try to compensate for the fall in the domestic demand for agri-food products*

Generally, exports of agri-food products from the EU tend to increase, whereas imports decrease as due to lower food prices EU agri-food products are able to compete better in the world market.

E. *across regions in the world: regions that export agri-food products for which EU demand falls generally suffer in terms of GDP, whereas other regions, which export products for which EU demand rises, generally gain.*

The GDP of Central and South America and North America generally slightly declines with that of EU GDP, due to the fall in exports of, notably, animal-based produce following from lower EU demand due to lower wastage or the adoption of a healthy diet. Similarly, the Middle East and North Africa seem to suffer from losses in exports to the EU of vegetables and fruits when food waste in the EU is reduced.

F. *over time:*

1. If reducing food waste was prolonged further, beyond the target year of 2020*, the trends observed would continue,* but it is likely that the path towards a more sustainable consumption pattern will have *decreasing returns* as it will be more difficult to reduce waste or change eating patterns (Section 5.10.4);
2. *Costs may be involved with reducing food waste by households and in retail in the short term* (for example time, packaging; currently not modelled due to lack of data), which may need to be borne up front with potential benefits occurring only later;
3. Also, *households may delay spending savings on previously wasted foods* (currently not modelled) so that observed benefits in other food or non-food markets are realised only later.

If reducing food waste, which in this study covers the period from 2012 to 2020, would take longer, the shown effects would also materialise over a longer period. The results can simply be extrapolated to a longer period of time. The direction and relative magnitudes of the results will not change.

S.3 Methodology and assumptions

We have employed a global computable general equilibrium model, *MAGNET,* to project impacts of *reducing food waste by EU households and in retail* and contrast this with a scenario in which EU households adopt a *healthy diet following WHO recommendations with respect to consumption of animal-based products* (Chapter 4). In order to isolate the impacts of the food waste and healthy diet scenarios, we take the baseline, Business as Usual, results out when reporting the results. In the Business as Usual scenario, major socio-economic drivers follow current trends and it is assumed that there are no major policy changes. We use *basic economic theory* elaborated in Rutten (2013) to frame and evaluate the outcomes (Chapter 3).

The analysis, to our knowledge, is the first detailed and applied study on impacts associated with reducing food waste by households and retail in the EU. It advances the study by Westhoek et al. (2011), by using real and more detailed data on food waste on the demand side. Although exact figures may differ, major trends found in this report are in line with those of Westhoek et al. (2011), notably the fall in demand for agri-food products following food waste reductions, land use savings in the EU, an increase in food availability and decrease in food prices benefiting net food consumers and harming net food producers, and a healthier diet option having larger impacts (see Section 5.10.4) .

Given the limited information base for carrying out the work, several key assumptions had to be made which may affect the outcomes and need further research. These are listed below.

1. If households reduce food waste, it is assumed that this results in less demand for the food commodity or commodities in question and, in the absence of knowledge on how the saved expenditures will be used, that *households subsequently increase demand for all (food and non-food) commodities by the same proportion and to the extent that households remain on their budget constraint*. If, as an extreme alternative, it is assumed that households would spend all savings from previously wasted foods on food commodities, then the net impact on agri-food sectors would be much less as would be the impact on land use and the economy at large. The main impact would be on EU consumers in terms of increased welfare (higher utility). The other extreme is that households spend all savings on non-food commodities (products and services), in which case agri-food sectors would be hurt more. The assumption made lies in between these two extremes and does some justice to consumer preferences, which over time, as incomes

rise, shift from food towards non-food commodities, and within food towards more luxurious food items.

2. The *waste data* are from *FAO*'s publication 'Global food losses and food waste: extent, causes and prevention', published in 2011 and contain data for Europe (including Russia), but at a detailed commodity level (Chapter 2). In the absence of reliable evidence on by how much this can be reduced or avoided, we calculate impacts on the basis of given *modest* (30% reduction), *realistic* (40% reduction) *and ambitious* (50% reduction) *targets to be realised in 2020*, the latter target being modelled on the milestone set by the EU in 2020 (as specified in the 'Roadmap to a Resource Efficient Europe'). *Waste and waste reductions are taken as given*; given the lack of information, we abstract from underlying causes of food waste which have not been quantified as yet (e.g. low food prices).

3. In the absence of reliable evidence on potential costs associated with reducing waste by households and in retail, the outcomes of this study are *conditional on the assumption that costs that may be associated with reducing household and retail waste are absent.*

4. *Other modelling issues.* We were asked to investigate the impacts of reducing food waste in demand, i.e. by households and in retail. The latter sector in the model includes wholesale, hotels and restaurants. To do justice to the different nature of food waste in food service sectors compared with retail, further research should split out these sectors. More detail is also required regarding households, which may differ in terms of waste behaviour, but also in terms of how they are affected (e.g. rural versus urban). LEI Wageningen UR is currently working on incorporating multiple households. How the reductions in food waste on the demand side in the EU interact with and compare to reductions in losses on the supply side is also an area for future research. The same is true for implications for water use, biodiversity and GHG emissions, and health and health cost impacts, which are currently better addressed in combination with or by other models.

Samenvatting

S.1 Belangrijkste uitkomsten

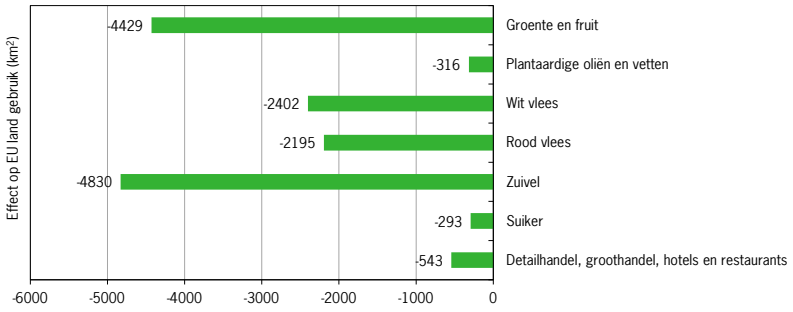
1. *De vermindering van voedselverspilling door huishoudens in de EU leidt tot een jaarlijkse besparing voor de huishoudens van 92 euro per hoofd van de bevolking (30% vermindering van de huishoudelijke verspilling in 2020), 123 euro per hoofd van de bevolking (40% vermindering in 2020) of 153 euro per hoofd van de bevolking (50% vermindering in 2020). Dit komt voor de EU als geheel neer op een totale jaarlijkse besparing van 56,6, 75,5 of 94,4 miljard euro voor de verschillende scenario's van respectievelijk 30%, 40% of 50% minder verspilling. Vergeleken met het gemiddelde EU-huishoudbudget dat aan voedsel wordt besteed, vertegenwoordigt dit een besparing van respectievelijk 5%, 7% of 9%.*

Omdat we niet weten hoe het bespaarde geld gebruikt wordt, nemen we aan dat alle sectoren van de economie (food- en non-foodproducten) in dezelfde mate profiteren van de geldmiddelen die dankzij de vermindering van de voedselverspilling door de huishoudens vrijkomen. Hierdoor stijgt het welvaartsniveau van de huishoudens. De herverdeling van de huishoudelijke uitgaven - van uitgaven voor verspild voedsel naar uitgaven voor andere food- en non-foodsectoren - brengen veranderingen op economisch vlak met zich mee, waar sommige sectoren profijt van hebben en andere juist niet (paragraaf 5.10.2). De gevolgen die uit de modelberekening naar voren komen, zijn hieronder (punt 2 t/m 7) beschreven voor het realistische scenario (40% minder voedselverspilling).

2. *Het totale oppervlak aan landbouwgrond dat door de vermindering van voedselverspilling door de huishoudens en de detailhandel in de EU kan worden bespaard, is aanzienlijk: 28.940 km^2 bijna het totale oppervlak van België (ongeveer 1,6% van de landbouwgronden in de EU in 2020).*

Dit vrijgekomen land kan bijvoorbeeld worden gebruikt voor voedselproductie voor de export naar andere landen of voor de productie van biobrandstoffen om te voldoen aan de energiebehoefte in de EU.

Figuur S.1 **Gevolgen voor het landgebruik in 2020 door vermindering van de huishoudelijke voedselverspilling van een geselecteerd aantal goederen en door vermindering van de verspilling in de detailhandel in de EU [a)]**



a) Resultaten van het realistische scenario (vermindering van 40%). Het totale oppervlak van de landbouwgrond in de EU wordt geschat op 1,8m km^2 in 2020. Aangezien 1 km^2 = 100 ha (hectare), komt dit neer op 180m ha. Suiker bevat rauwe suiker, melasse en andere zoetstoffen.

3. *Het grootste deel van de landbouwgrond komt vrij dankzij:*
   i. *zuivelproducten,* omdat deze nauw verbonden zijn met de sectoren van levende dieren (vee produceert rauwe melk) en diervoeder (granen; paragraaf 5.3.3);
   ii. *groente en fruit,* waarvan de huishoudens relatief veel verspillen (paragraaf 5.2.3);
   iii. *rood en wit vlees,* dat ook in sterke mate verbonden is met de sectoren van levende dieren (kippen, varkens, vee) en diervoeder (paragraaf 5.1.3 en 5.4.3).

Dankzij de vermindering van de huishoudelijke verspilling van zuivelproducten kan 17% van de landbouwgrond worden vrijgemaakt en nog eens 15% dankzij de groente- en fruitteelt. Samen is dit ongeveer tweemaal het landoppervlak dat kan worden bespaard door de huishoudelijke verspilling van rood vlees (8%) en wit vlees (8%) te verminderen.

4. *De vermindering van de gezamenlijke voedselverspilling van de huishoudens en de detailhandel heeft relatief weinig effect op de economie van de EU (het BBP van de EU in 2020 is 0,09% lager dan geraamd): de EU laat over de periode 2012-2020 een baseline BBP-groei zien van ongeveer 17%.*

Het kleine minteken voor het BBP laat zien dat de verminderde voedselverspilling van de huishoudens en de detailhandel een lagere vraag oplevert naar bepaalde voedingswaren ten gunste van andere food- en non-foodproducten, maar netto een iets lagere toegevoegde waarde genereert voor de economie van de EU. Het BBP is echter geen goede indicator voor de algemene welvaart, omdat de eerder vermelde verhoogde welvaart van de consumenten hier niet in is opgenomen.

5. *Sectoren die een positieve bijdrage leveren aan het BBP van de EU zijn onder meer:*
   i. *vermindering van de huishoudelijke verspilling van groente en fruit;*
   ii. *minder verspilling in de detailhandel* (in dit model omvat deze sector groothandels, hotels en restaurants).

De vermindering van huishoudelijke verspilling van groente en fruit biedt veel potentieel, omdat er veel beperkt houdbaar voedsel wordt weggegooid. Bovendien lijkt dit een positief effect te hebben op de economie van de EU, omdat er meer wordt uitgegeven aan andere producten met een hogere toegevoegde waarde (zie paragraaf 5.2.1). De vermindering van de verspilling in de detailhandel leidt tot lagere kosten en meer verkoop, dat een positief effect heeft op de rest van de economie van de EU.

6. *Gemiddeld is de invloed van de verminderde voedselverspilling door huishoudens en de detailhandel in de EU op de voedselzekerheid in Sub-Sahara Afrika weliswaar positief, maar relatief klein.*

Het is opvallend dat ook hier de grootste bijdragen afkomstig zijn van de verminderde voedselverspilling van groente en fruit door Europese huishoudens. Deze voordelen komen wellicht echter alleen ten goede aan stedelijke huishoudens, omdat de dalende prijzen waarschijnlijk een lager inkomen voor de landelijke huishoudens met zich meebrengen, die voor hun levensonderhoud afhankelijk zijn van de landbouw. De beperkte invloed op de voedselzekerheid voor het gemiddelde huishouden - vooral in Sub-Sahara Afrika, maar ook in andere ontwikkelingsgebieden - doet vermoeden dat, als voedselzekerheid het voornaamste punt van zorg is, het beter is om de aandacht op een ander beleid te richten dan het terugdringen van verspilling, bijvoorbeeld beleid dat de toegang tot de markt of het investeringsklimaat in deze regio's verbetert (paragraaf 5.10.2).

7. *Het aannemen van een gezond voedingspatroon levert over het algemeen meer resultaat op dan het verminderen van de verspilling door huishoudens en de detailhandel in de EU (paragraaf 5.10.3). Vergeleken met het laatstgenoemde, zorgt het eerstgenoemde voor:*

i. *een halvering van de daling van het BBP in de EU*

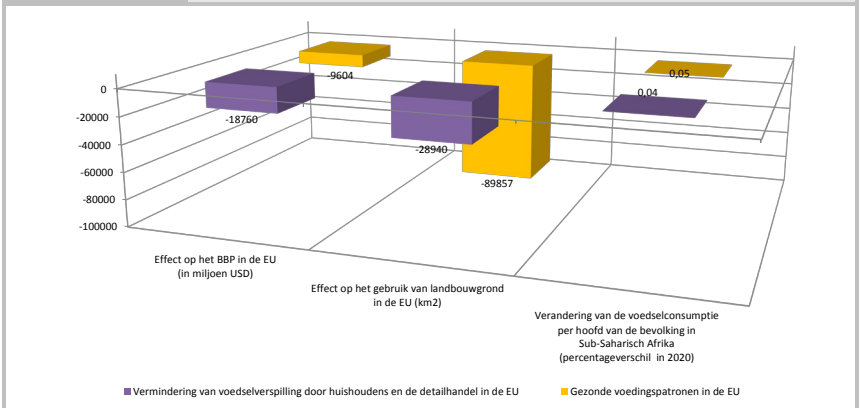
De vermindering van verspilling door huishoudens en de detailhandel heeft negatieve effecten op alle agrifoodsectoren. Een gerichte vermindering van de vraag naar dierlijke producten daarentegen schaadt de hieraan verbonden sectoren, maar is gunstig voor andere agrifoodsectoren, aangezien de huishoudens de dierlijke producten gaan vervangen door gezondere voedingsmiddelen (zoals groente en fruit, plantaardige oliën en vetten en dergelijke).

ii. *een afname van het gebruik van EU-landbouwgrond met een factor 3*

De dierlijke (vlees- en melk)sectoren zijn relatief dichter verweven met de rest van de economie, vooral met de vee- en diervoedersector. Als gevolg daarvan heeft de daling van de vraag, die immers veel groter is in de dierlijke sectoren, een groter negatief effect op het landgebruik, mede doordat het effect van het eten van gezonde voeding op voedselconsumptie en productie relatief groot is vergeleken met het effect van minder voedselverspilling.

iii. *een ogenschijnlijk groter effect op de stijging van de voedselzekerheid van het gemiddelde huishouden in Sub-Sahara Afrika, hoewel het effect erg klein is*

Figuur S.2 **De vermindering van voedselverspilling door huishoudens en de detailhandel vergeleken met de overgang naar een gezond voedingspatroon in de EU in 2020** [a)]



a) Resultaten van de vermindering van voedselverspilling door Europese huishoudens en de detailhandel in het realistische scenario (vermindering van 40%). Het BBP is berekend in constante USD (2007). Het BBP en de landbouwgrond in de EU worden in 2020 respectievelijk geschat op 20 biljoen USD en 1,8m km^2, ervan uitgaande dat de huidige trends zich voortzetten en dat er geen nieuw beleid komt.

Deze bevindingen suggereren dat het beter is om het reduceren van voedselverspilling door huishoudens en de detailhandel in de EU te combineren met - duurzamere - gedragsveranderingen die moeten leiden tot een gezond voedingspatroon. Als andere industrielanden vergelijkbare actie ondernemen, zijn de effecten nog groter.

S.2 Overige uitkomsten

De totale vermindering van de voedselverspilling van huishoudens en de detailhandel of het eten van gezondere voeding leidt tot wisselwerkingen, dat wil zeggen dat er winnaars en verliezers zullen zijn (paragraaf 5.10.1):

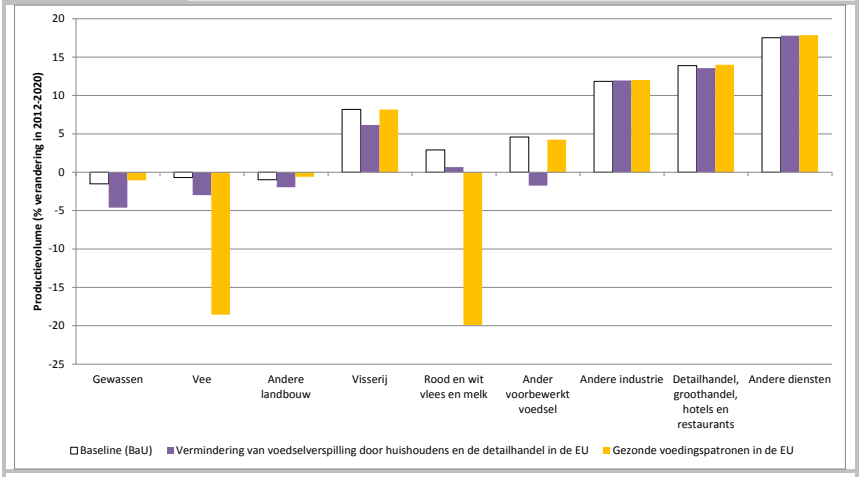
A. *tussen producenten in de EU:*

Middelen verdwijnen uit de sectoren die lijden onder de afgenomen vraag, omdat er minder voedsel wordt verspild of omdat het voedselpatroon gezonder is (dierlijke sectoren) en gaan naar andere sectoren die profiteren van de extra middelen die zodoende vrijkomen. De dierlijke sectoren (zuivelproducten, rood en wit vlees) zijn relatief sterk verweven met de bijbehorende sectoren van le-

vende dieren (vee, rauwe melk van melkkoeien, kippen en varkens) en diervoeding (granen), zodat een negatief effect op de dierlijke sectoren ook de andere sectoren negatief zal beïnvloeden (zie paragrafen 5.1.2, 5.3.2 en 5.4.2). Er bestaat een vergelijkbaar effect tussen suiker (inclusief ruwe suiker, molasse en andere zoetstoffen) en de suikerriet- en suikerbietsectoren (paragraaf 5.5.2). De detailhandel en de sector 'overig voedsel' (zie respectievelijk paragraaf 5.7 en 5.6) zijn doorgaans van grotere omvang en in grotere mate verbonden met alle andere agrifoodsectoren. Dit verklaart waarom een lagere voedselverspilling hier, en met name in de sector 'overig voedsel', een groter effect heeft.

Als de voedselverspilling van huishoudens en de detailhandel in de EU voor alle voedingswaren vermindert, dan raakt dit alle agrifoodsectoren en zal het volume gemiddeld met 4,4% dalen, vergeleken met de projecties voor 2020 (in de baseline). Middelen verdwijnen uit de agrifoodsectoren naar de industrie- en dienstensectoren, die licht gaan groeien.

Figuur S.3 **Veranderingen van de productievolumes in 2012-2020 voor de scenario's van de baseline, verminderde voedselverspilling [a] en een gezonder voedingspatroon**



a) Resultaten van de vermindering van de voedselverspilling van Europese huishoudens en de detailhandel in het realistische scenario (vermindering van 40%).

B. *ten aanzien van de effecten op de werkgelegenheid in de EU:*

De werkgelegenheid en de reële lonen in de primaire landbouwsectoren in de EU dalen, terwijl de werkgelegenheid en de reële lonen in de industrie- en dienstensector stijgen.
Dit versterkt alleen maar het lopende proces waarbij het belang van de landbouwsector afneemt en het belang van industrie en diensten in de economie van de EU steeds belangrijker wordt. Het suggereert dat er extra beleid ter ondersteuning van de landbouw nodig kan zijn om de landbouwsector tijdens deze overgangsperiode te ondersteunen.

C. *tussen producenten en consumenten in de EU:*

Deze laatsten zijn beter af, omdat hun welvaart stijgt door de lagere verspilling en zij hiervan profiteren in termen van voedselzekerheid:
Als de kwaliteit van het voedselpatroon even buiten beschouwing wordt gelaten, profiteren de huishoudens in de EU van lagere voedselprijzen en grotere voedselconsumptie (verspilling niet meegerekend) dankzij het geld dat wordt bespaard op voedsel dat voorheen werd verspild (zie paragraaf 5.8.1). De trend van een gezond voedingspatroon in de EU impliceert echter een daling van de consumptie van dierlijke producten door de huishoudens in de EU, die opweegt tegen de stijging van de consumptie van andere agrifoodproducten (zie paragraaf 5.9.1). Bovendien zal door de vermindering van de verspilling door de detailhandel in de EU (inclusief groothandels, hotels en restaurants) de vraag van EU-huishoudens naar agrifoodproducten afnemen ten gunste van relatief goedkopere vis, detailhandelsproducten en andere diensten en daardoor zal de voedselconsumptie van de huishoudens in de EU dalen (zie paragraaf 5.7.1).

D. *voor beleidsdoelstellingen in de EU (zie tabel 5.1, paragraaf 5.10.1):*

De hiervoor genoemde lichte daling van het BBP moet worden afgewogen tegen een toenemende voedselzekerheid en welvaart van consumenten, maar ook tegen de positieve effecten in termen van vrijgekomen landbouwgrond, de licht negatieve effecten veroorzaakt door een gewijzigd (ongezonder) voedselpatroon, en een verbeterd handelspatroon:

1. *de EU bespaart meer op landgebruik*
Het landgebruik in de EU verandert in het algemeen in lijn met de ontwikkelingen in de sectoren, met enige verschuiving van krimpsectoren naar groeisectoren.

We zien dat een daling in grondprijzen door de verminderde vraag naar sommige agrifoodproducten leidt tot een toegenomen vraag naar grond in andere landbouwsectoren. Deze secondaire effecten zijn echter relatief klein, zodat het totale landgebruik altijd daalt.

2. *voedingspatronen in de EU worden over het algemeen iets minder gezond, gemeten naar het aandeel van dierlijke producten in het huishoudbudget, als in de EU minder verspild wordt.*

De op de voedselverspilling bespaarde bedragen worden iets meer besteed aan 'luxere' goederen, inclusief dierlijke producten. Dit wil zeggen dat EU-consumenten hun consumptiepatroon 'naar boven' (naar meer kwalitatief hoogwaardige producten) bijstellen. De effecten zijn klein, omdat de besparingen op de voedselverspilling verspreid worden over alle door huishoudens geconsumeerde goederen.

3. *handelspatronen binnen de EU proberen over het algemeen de daling van de binnenlandse vraag naar agrifoodproducten te compenseren.*

Doorgaans heeft de export van agrifoodproducten uit de EU de neiging om te stijgen, terwijl de import daalt omdat door de prijsdaling EU agrifoodproducten iets beter kunnen concurreren in de wereldmarkt.

E. *verspreid over regio's wereldwijd: regio's die agrifoodproducten exporteren waar in de EU een dalende vraag naar is, zien dit terug in de daling van hun BBP, terwijl regio's die producten exporteren waar in de EU een groeiende vraag naar is, over het algemeen profiteren.*

Het BBP van Zuid-, Midden- en Noord-Amerika daalt over het algemeen licht, tegelijkertijd met het BBP van de EU. Dit is te wijten aan de gedaalde export van vooral dierlijke producten, veroorzaakt door de afgenomen vraag uit de EU vanwege de verminderde verspilling en de overgang naar een gezond voedingspatroon. Tegelijkertijd lijken het Midden-Oosten en Noord-Afrika te lijden onder de dalende export van groente en fruit naar de EU als de voedselverspilling in de EU afneemt.

F. *op termijn:*

1. Als de voedselverspilling na het streefjaar 2020 nog verder wordt verminderd, *zetten de geconstateerde trends* door, maar het is waarschijnlijk dat het pad naar een duurzamer consumptiepatroon *dalende resultaten* zal laten

zien, omdat het steeds moeilijker zal worden om nog minder te verspillen of de voedingspatronen te veranderen (paragraaf 5.10.4);
2. *Op korte termijn kan de vermindering van de voedselverspilling door de huishoudens en in de detailhandel kosten met zich meebrengen* (bijvoorbeeld tijd, verpakkingsmateriaal; op dit moment nog niet beraamd door een gebrek aan gegevens) die vooraf moeten worden gedragen en waarvan de potentiële voordelen pas later zichtbaar worden;
3. Ook kunnen *huishoudens bijvoorbeeld wachten met het uitgeven van het geld dat ze door de verminderde voedselverspilling hebben bespaard* (momenteel niet gemodelleerd), zodat de geconstateerde winst voor andere food- of non-foodmarkten pas later wordt behaald.

Als de vermindering van de voedselverspilling - die in deze studie de periode van 2012 tot 2020 beslaat - langer duurt, worden de aangetoonde effecten ook over een langere periode zichtbaar. De resultaten kunnen gewoon over een langere tijdsperiode worden geëxtrapoleerd. De tendens en de relatieve grootte van de resultaten veranderen niet.

S.3 Methodologie en aannames

We hebben gebruik gemaakt van een toegepast algemeen evenwichtsmodel, *MAGNET,* om de effecten van de *verminderde voedselverspilling van de huishoudens en de detailhandel in de EU te ramen* en dit af te zetten tegen een scenario waarin de Europese huishoudens overgaan op een *gezond voedingspatroon volgens de aanbevelingen van de WHO voor de consumptie van dierlijke producten* (hoofdstuk 4). Om de effecten van de scenario's voor de voedselverspilling en een gezond voedingspatroon te isoleren, laten we bij de presentatie de 'Business as Usual'-uitgangsresultaten buiten beschouwing. In het 'Business as Usual'-scenario volgen de belangrijkste sociaal-economische factoren de huidige trends en gaan we ervan uit dat er geen belangrijke beleidsveranderingen plaatsvinden. We gebruiken standaard *economische theorie* die door Rutten (2013) is uitgewerkt in een analytisch raamwerk om de uitkomsten te kaderen en te evalueren (hoofdstuk 3).

Het onderzoek is, voor zover wij weten, de eerste gedetailleerde en toegepaste studie over de gevolgen van vermindering van de voedselverspilling door de huishoudens en de detailhandel in de EU. Het vormt een uitbreiding op de studie van Westhoek et al. (2011) door gebruik te maken van reële en meer gedetailleerde gegevens over voedselverspilling aan de vraagkant. En hoewel exacte cijfers kunnen verschillen, komen de belangrijkste trends in dit rapport

overeen met de bevindingen van Westhoek et al. (2011), vooral de daling van de vraag naar agrifoodproducten door de verminderde voedselverspilling, landbesparing in de EU en verhoging van de voedselbeschikbaarheid en de daling van de voedselprijzen die ten goede komen aan de consumenten van voedsel en de voedselproducenten schaden, en een gezonder voedingspatroon dat grotere effecten heeft (zie paragraaf 5.10.4).

Gezien de beperkte informatiebasis moesten we aannames doen ten aanzien van verschillende belangrijke uitgangspunten die de uitkomsten kunnen beïnvloeden en verder onderzoek vereisen. Deze staan hieronder vermeld.

1. Als huishoudens minder voedsel verspillen, wordt aangenomen dat dit de vraag naar voedingswaren of de producten in kwestie verlaagt en dat, bij gebrek aan kennis over de manier waarop het bespaarde geld zal worden besteed, de *huishoudens hun vraag naar allerlei producten (food en non-food) in dezelfde mate zullen verhogen, ervan uitgaande dat de huishoudens zoals voorheen hun budget volledig zullen opmaken.* Indien, als een extreem alternatief, wordt aangenomen dat de huishoudens al het op de voedselverspilling bespaarde geld uitgeven aan voedsel of voedingswaren, dan zal het netto effect op de agrifoodsectoren veel kleiner zijn, alsook de impact op het landgebruik en de economie in het algemeen. Het voornaamste effect zal worden gevoeld door consumenten in de EU in termen van een verhoogde welvaart (nutsniveau). Het andere extreme alternatief is dat de huishoudens al hun bespaarde geld gaan besteden aan non-foodproducten (producten en diensten), in welk geval de agrifoodsectoren zwaarder getroffen zouden worden. Onze aanname ligt tussen deze twee extremen in en doet recht aan de voorkeuren van de consumenten die op termijn, als hun inkomen stijgt, overgaan van food- naar non-foodproducten en binnen de voedselproducten naar meer luxe voeding.

2. De *verspillingsgegevens* zijn afkomstig van de in 2011 gepubliceerde *FAO*-publicatie 'Global food losses and food waste: extent, causes and prevention' en bevatten gegevens over Europa (inclusief Rusland), maar op een gedetailleerd productniveau (hoofdstuk 2). Bij gebrek aan betrouwbaar bewijs van de mate waarin dit kan worden verminderd of vermeden, berekenen we de effecten op basis van *bescheiden* (30% vermindering), *realistische* (40% vermindering) *en ambitieuze* (50% vermindering) *doelen, te verwezenlijken in 2020*. Deze laatste doelstelling is gebaseerd op de mijlpaal die door de EU voor 2020 is vastgesteld (zoals bepaald in de 'Roadmap to a Resource Efficient Europe'). *Verspilling en vermindering van verspilling zijn vaststaande*

waarden; gezien het gebrek aan informatie zien we af van de onderliggende redenen van voedselverspilling die tot nu toe niet zijn gekwantificeerd (bijvoorbeeld lage voedselprijzen).

3. Bij gebrek aan betrouwbaar bewijs over potentiële kosten in verband met de vermindering van verspilling van de huishoudens en de detailhandel, zijn de uitkomsten van dit onderzoek *onder voorbehoud van de aanname dat er geen kosten gemoeid zullen zijn met de verminderde verspilling van de huishoudens en de detailhandel.*

4. *Andere kwesties die in dit model naar voren zijn gekomen.* Er werd ons gevraagd onderzoek te doen naar de effecten van de vermindering van voedselverspilling, dat wil zeggen in huishoudens en in de detailhandel. Deze laatste sector omvat ook de groothandels, hotels en restaurants. Om recht te doen aan de verschillende soorten voedselverspilling in de voedseldienstensectoren vergeleken met de detailhandel, zouden deze twee sectoren in een nader onderzoek gescheiden moeten worden. Er zijn ook meer gegevens nodig over de huishoudens, die kunnen verschillen in hun verspillingspatroon, maar ook wat betreft de effecten die dit op hen heeft (bijvoorbeeld landelijk versus stedelijk gebied). LEI Wageningen UR is op dit moment bezig verschillende typen huishoudens in het model te onderscheiden. Hoe de vermindering van voedselverspilling aan de vraagkant van de EU reageert op en zich verhoudt tot lagere voedselverliezen aan de aanbodkant, is ook een onderwerp voor nader onderzoek. Hetzelfde geldt voor de gevolgen voor watergebruik, biodiversiteit en broeikasgasemissies, de gezondheid en de effecten op de kosten van de gezondheidszorg, die op dit moment beter kunnen worden bekeken in combinatie met of aan de hand van andere modellen.

1 Introduction

1.1 Background of the project

This report was commissioned by BIO Intelligence Service as part of the project 'Modelling Milestones for achieving Resource Efficiency' (a project under framework contract Env.G.4/FRA/2008/0112 for DG Environment). The request to LEI Wageningen UR was to model the economic impacts of reducing food waste in the broader context of resource efficiency, which led us to also consider dietary change and look at impacts on land use next to impacts on various socio-economic indicators.

1.2 Project team

Marc-Jeroen Bogaardt and Lusine Aramyan gathered evidence on food losses and waste (Chapter 2). Martine Rutten has been responsible for the literature review on impacts (Chapter 2), the economic theory (Chapter 3), the modelling (Chapter 4), the analyses (Chapter 5) and writing the overall project report. Project coordination was in the hands of Peter Nowicki up to March 2013 and from March 2013 onwards taken over by Martine Rutten.

1.3 Acknowledgements

The authors acknowledge useful comments and advice on the chain perspective and the economic modelling by Yuca Waarts and Geert Woltjer, respectively. We are also grateful for the various comments, suggestions and feedback from Adrian Tan, Francois Cohen and Clementine O'Connor of BIO Intelligence Service throughout the research, and from Siemen van Berkum, Lindsay Shutes, Aikaterini Kavallari, Jo Wijnands, Andrzej Tabeau, Thom Achterbosch and Gerdien Meijerink on the interpretation of results and final reporting.

1.4 Structure of the report

This report is structured as follows: Chapter 2 provides a literature review on the evidence of food losses and waste, the extent by which it may be reduced and associated costs, and a review of the literature on impacts. Chapter 3 discusses what we can learn from economic theory on expected impacts using a graphical analysis. Chapter 4 describes the MAGNET model, the data used, the choice of factors, sectors and regions, the scenarios and how they have been set up, the indicators used to analyse the results, and delimitations of the analysis. Chapter 5 contains the results of the scenario analysis, presenting the results of the individual scenarios but also an overall discussion of the main patterns, a comparison of individual food waste scenarios and a comparison of how reducing food waste by households and retail in the EU performs compared with adopting a healthy diet. Chapter 6 concludes.

2 Literature review on the evidence on and expected impacts of reducing food losses and waste

This chapter reviews the literature on the evidence on food waste and losses, and the expected impacts that may occur if food losses and waste are reduced. The evidence not only concerns the extent of food losses and waste throughout the supply chain in the EU, but also the extent to which this waste can realistically be reduced and the cost associated with doing so.

The applied economic literature using economic modelling tools to derive potential impacts of food losses and/or waste, and the impacts of reducing these, is virtually non-existent. We therefore review what we can find in the qualitative literature on potential impacts. We focus on economic impacts (notably in terms of food security, prices and income) and land use and associated environmental impacts.

This report uses the definition of food losses and waste according to Parfitt et al. (2010) which states that *food losses* refer to the decrease in edible food mass (quantitative) throughout the part of the supply chain that specifically leads to edible food for human consumption. Food losses take place at production, postharvest handling and storage, processing and distribution stages in the food supply chain. Food losses occurring at the end of the food supply chain (at retail and final consumption stages) are rather called *food waste*, which relates to retailers' and consumers' behaviour. This concerns food as a final product, of good quality and fit for consumption, but does not get consumed because it is discarded, whether or not after it is left to spoil.

2.1 Evidence on EU food losses and waste in the supply chain

The total quantity of food lost and wasted in Europe in 2006 has been estimated to be 121.8m tonnes. That is 247 kg per capita for approximately 493.2m EU inhabitants (see Table 2.1). Compared with the total food production in the EU for 2006, 766.2m tonnes (see Table 2.2), the total food loss and waste is about 16%.

Table 2.1	Food losses and waste in five sectors of the food supply chain in EU27 in 2006 (in tonnes and percentages) a)			
Sector	**Food losses and waste (in tonnes)**	**Food losses and waste (in kg/ capita)**	**Food losses and waste (in %)**	**Food losses / waste**
Agriculture, hunting & forestry	32,636,495	66.2	26.8	Food loss
Manufacturing	34,791,269	70.5	28.6	
Wholesale/retail	4,433,333	9.0	3.6	Food waste
Food service/catering	12,263,212	24.9	10.1	
Households	37,701,760	76.4	30.9	
Total	121,826,069	247	100%	

a) We have combined the data on animal and vegetal waste in the agriculture, hunting and forestry sector (BIO, 2011: p42) together with the data on total food waste generation in the other sectors (BIO, 2011: p63).
Source: data from BIO (2011), adapted by LEI.

Table 2.1 shows that the household sector generates the highest proportion of avoidable[1] food losses and waste, namely 30.9% of the total of 122m tonnes in the EU, which is about 37.7m tonnes, an average of 76 kg per capita. The manufacturing sector generates 28.6% of total food losses and waste, almost 35m tonnes in 2006 in the EU27, which according to stakeholders is predominantly unavoidable food loss. The wholesale/retail sector is generating the smallest proportion of food losses and waste at 3.6%, although very limited data were available for this sector and thus this estimate should be considered with caution.

Table 2.2a presents the total food losses and waste *in tonnes* within the five sectors of the food supply chain in the 27 EU Member States in 2006, based on the available data and expert judgement. Table 2.2a shows a high heterogeneity between Member States, e.g. in manufacturing (i.e. food processing industry). This has to do with the geographic repartition of the EU food industry, which is highly concentrated in certain countries and less in others.

Table 2.2b presents the food losses and waste *in kg/capita* in each of the 27 EU Member States, based on the population in 2006.

The Netherlands

More detailed studies may give different figures, because of differences in sampling or in aggregation within the different categories of food loss or waste. For

[1] For definitions of avoidable and unavoidable food waste see Parfitt et al. (2010).

example, according to Table 2.2b the household food waste in the Netherlands in 2006 is 112.5 kg per capita. But according to a national study published after the Preparatory Study had completed its quantification, the household food waste in the Netherlands amounts to approximately 73 kg per capita in 2010: 78% via household waste, 13% via vegetables, fruit and garden waste and 9% is wasted through the sewer. Of the 73 kg, approximately 44 kg is avoidable (edible, so a waste of 60%) and about 29 kg is unavoidable (inedible, such as shells and bones, so 40%) (Westerhoven, 2010: p8). Two years later, in 2012, an increase of 68% of avoidable food waste in nineteen large and small municipalities in the Netherlands was noted. If this trend is extrapolated to the national level, the avoidable waste of edible food would be 74 kg per capita per year instead of 44 kg (CREM, 2013).

United Kingdom

Other examples of differences in figures available come from the 2010 WRAP study, which estimated that food and drink manufacturers in the UK lose about 16% of their raw materials during manufacturing (see also Foresight, 2011: p9). A separate study by the European Commission estimates that 39% of total food losses, excluding losses at the farm level, are generated at the manufacturing stage (Gunders, 2012: p9). At the retail and distribution stage, the most recent estimate for the UK suggests that the losses are relatively small at 366,000 tonnes per year, which is 2.6% of the total food waste (Foresight, 2011: 11). Another study (Gooch, 2011: 4) states that the vast majority of UK food waste could be avoided, with the exception of about 20% that is inedible food material;

Considering the differences found in the studies available, this study does not attempt to establish a synthesis, but rather adopts one information source (FAO, 2011; discussed later) for the quantities of food losses and waste that will be used for the data incorporated in the modelling work.

Table 2.2a **Food losses and waste (in tonnes) in five sectors of the food supply chain in the 27 EU MS in 2006 a)**

	Sector	Food production	Agriculture, hunt & forestry			Manufacturing			Wholesale/retail			Food service/catering			Households			Total
EU Member States		(tonnes)	(tonnes)	(in %)		(tonnes)	(in %)		(tonnes)	(in %)		(tonnes)	(in %)		(tonnes)	(in %)		(tonnes)
Northern EU	**Sweden**	5,197,871	3,122,000	62.0%		601,327	11.9%		110,253	2.2%		298,880	5.9%		905,000	18.0%		5,037,460
	Finland	9,845,332	2,334	0.2%		626,000	60.6%		46,708	4.5%		143,570	13.9%		214,796	20.8%		1,033,408
	Denmark	9,103,122	997	0.1%		101,646	12.8%		45,676	5.8%		148,266	18.7%		494,914	62.5%		791,499
	United Kingdom	87,004,770	22,500	0.2%		2,591,000	18.1%		366,000	2.6%		3,000,000	21.0%		8,300,000	58.1%		14,279,500
	Ireland	5,382,309	1,568	0.2%		465,945	51.1%		37,407	4.1%		114,981	12.6%		292,326	32.0%		912,227
	Netherlands	50,834,267	1,256,541	12.4%		6,412,330	63.5%		145,166	1.4%		446,213	4.4%		1,837,599	18.2%		10,097,849
	Belgium	27,470,839	170,682	4.5%		2,311,847	60.9%		93,417	2.5%		287,147	7.6%		934,760	24.6%		3,797,853
	Luxembourg	0	691	0.8%		2,665	3.2%		4,169	5.0%		12,814	15.5%		62,538	75.5%		82,877
	Germany	138,078,334	525,441	4.1%		1,848,881	14.5%		732,646	5.7%		2,000,000	15.6%		7,676,471	60.1%		12,783,439
	Austria	9,914,359	9,500	0.5%		570,544	32.9%		267,000	15.4%		103,500	6.0%		784,570	45.2%		1,735,114
	Average				8.5%			33.0%			4.9%			12.1%			41.5%	
NMS	**Poland**	47,233,940	16,462,589	63.6%		6,566,060	25.4%		339,111	1.3%		457,130	1.8%		2,049,844	7.9%		25,874,734
(Eastern EU)	**Czech Republic**	13,034,071	123,559	13.0%		361,813	37.9%		91,104	9.6%		122,810	12.9%		254,124	26.7%		953,410
	Estonia	1,143,852	24,036	6.3%		237,257	62.4%		11,951	3.1%		24,564	6.5%		82,236	21.6%		380,044
	Latvia	1,606,037	38,049	13.1%		125,635	43.2%		20,393	7.0%		27,490	9.5%		78,983	27.2%		290,550
	Lithuania	4,020,685	271,599	40.2%		222,205	32.9%		30,246	4.5%		40,772	6.0%		111,160	16.4%		675,982
	Hungary	11,702,284	311,772	15.0%		1,157,419	55.8%		89,553	4.3%		120,720	5.8%		394,952	19.0%		2,074,416
	Bulgaria	4,849,152	255,754	24.0%		358,687	33.7%		68,598	6.4%		92,472	8.7%		288,315	27.1%		1,063,826
	Romania	10,845,823	8,037,598	83.1%		487,751	5.0%		192,055	2.0%		258,895	2.7%		696,794	7.2%		9,673,093
	Slovakia	3,841,080	41,357	6.5%		347,773	54.6%		47,895	7.5%		64,564	10.1%		135,854	21.3%		637,443
	Slovenia	1,176,515	6,521	4.3%		42,072	28.0%		17,804	11.8%		11,405	7.6%		72,481	48.2%		150,283
	Average				26.9%			37.9%			5.8%			7.2%			22.3%	
Southern EU	**France**	106,199,337	453,300	5.0%		626,000	6.9%		561,935	6.2%		1,080,000	11.9%		6,322,944	69.9%		9,044,179
	Italy	97,088,841	98,652	0.9%		5,662,838	53.4%		522,140	4.9%		1,604,960	15.1%		2,706,793	25.5%		10,595,383
	Spain	101,939,483	1,046,681	15.1%		2,170,910	31.3%		388,890	5.6%		1,195,374	17.2%		2,136,551	30.8%		6,938,406
	Portugal	12,496,826	41,057	2.8%		632,395	43.9%		93,934	6.5%		288,737	20.0%		385,063	26.7%		1,441,186
	Malta	0	7,481	19.5%		271	0.7%		3,599	9.4%		4,852	12.7%		22,115	57.7%		38,318
	Greece	6,170,557	284,662	24.3%		73,081	6.2%		98,872	8.4%		303,914	25.9%		412,758	35.2%		1,173,287
	Cyprus	0	19,574	7.2%		186,917	69.2%		6,811	2.5%		9,182	3.4%		47,819	17.7%		270,303
	Average				10.7%			30.2%			6.2%			15.2%			37.7%	
EU-27	Average			15.9%			34.1%			5.6%			11.1%			33.4%		
EU-27	**Total**	**766,179,686**	**32,636,495**	**26.8%**		**34,791,269**	**28.6%**		**4,433,333**	**3.6%**		**12,263,212**	**10.1%**		**37,701,760**	**30.9%**		**121,826,069**

a) To calculate the food waste in percentages we have used the data on food production in each Member State on page 48 of the BIO report (2011), together with the data on animal and vegetal waste in the agriculture, hunting and forestry sector in each Member State (BIO, 2011: p42) and the data on total food waste generation in the four other sectors (BIO, 2011: p63).
Source: data from BIO (2011), adapted by LEI.

Table 2.2b **Food losses and waste (per kg/capita) in five sectors of the food supply chain in the 27 EU MS in 2006 a)**

	Sector	Population	Agriculture, hunt & forestry			Manufacturing			Wholesale/retail			Food service/catering			Households			Total
EU Member States			(tonnes)	kg/capita		(tonnes)	kg/capita		(tonnes)	kg/capita		(tonnes)	kg/capita		(tonnes)	kg/capita		kg/capita
Northern EU	**Sweden**	9,047,752	3,122,000	345.1		601,327	66.5		110,253	12.2		298,880	33.0		905,000	100.0		556.8
	Finland	5,255,580	2,334	0.4		626,000	119.1		46,708	8.9		143,570	27.3		214,796	40.9		196.6
	Denmark	5,427,459	997	0.2		101,646	18.7		45,676	8.4		148,266	27.3		494,914	91.2		145.8
	United Kingdom	60,393,100	22,500	0.4		2,591,000	42.9		366,000	6.1		3,000,000	49.7		8,300,000	137.4		236.4
	Ireland	4,209,019	1,568	0.4		465,945	110.7		37,407	8.9		114,981	27.3		292,326	69.5		216.7
	Netherlands	16,334,210	1,256,541	76.9		6,412,330	392.6		145,166	8.9		446,213	27.3		1,837,599	112.5		618.2
	Belgium	10,511,382	170,682	16.2		2,311,847	219.9		93,417	8.9		287,147	27.3		934,760	88.9		361.3
	Luxembourg	469,086	691	1.5		2,665	5.7		4,169	8.9		12,814	27.3		62,538	133.3		176.7
	Germany	82,437,995	525,441	6.4		1,848,881	22.4		732,646	8.9		2,000,000	24.3		7,676,471	93.1		155.1
	Austria	8,254,298	9,500	1.2		570,544	69.1		267,000	32.3		103,500	12.5		784,570	95.0		210.2
	Average				44.9			106.8			11.2			28.3			96.2	
NMS	**Poland**	38,157,055	16,462,589	431.4		6,566,060	172.1		339,111	8.9		457,130	12.0		2,049,844	53.7		678.1
(Eastern EU)	**Czech Republic**	10,251,079	123,559	12.1		361,813	35.3		91,104	8.9		122,810	12.0		254,124	24.8		93.0
	Estonia	1,344,684	24,036	17.9		237,257	176.4		11,951	8.9		24,564	18.3		82,236	61.2		282.6
	Latvia	2,294,590	38,049	16.6		125,635	54.8		20,393	8.9		27,490	12.0		78,983	34.4		126.6
	Lithuania	3,403,284	271,599	79.8		222,205	65.3		30,246	8.9		40,772	12.0		111,160	32.7		198.6
	Hungary	10,076,581	311,772	30.9		1,157,419	114.9		89,553	8.9		120,720	12.0		394,952	39.2		205.9
	Bulgaria	7,718,750	255,754	33.1		358,687	46.5		68,598	8.9		92,472	12.0		288,315	37.4		137.8
	Romania	21,610,213	8,037,598	371.9		487,751	22.6		192,055	8.9		258,895	12.0		696,794	32.2		447.6
	Slovakia	5,389,180	41,357	7.7		347,773	64.5		47,895	8.9		64,564	12.0		135,854	25.2		118.3
	Slovenia	2,003,358	6,521	3.3		42,072	21.0		17,804	8.9		11,405	5.7		72,481	36.2		75.0
	Average				100.5			77.3			8.9			12.0			37.7	
Southern EU	**France**	63,229,443	453,300	7.2		626,000	9.9		561,935	8.9		1,080,000	17.1		6,322,944	100.0		143.0
	Italy	58,751,711	98,652	1.7		5,662,838	96.4		522,140	8.9		1,604,960	27.3		2,706,793	46.1		180.3
	Spain	43,758,250	1,046,681	23.9		2,170,910	49.6		388,890	8.9		1,195,374	27.3		2,136,551	48.8		158.6
	Portugal	10,569,592	41,057	3.9		632,395	59.8		93,934	8.9		288,737	27.3		385,063	36.4		136.4
	Malta	405,006	7,481	18.5		271	0.7		3,599	8.9		4,852	12.0		22,115	54.6		94.6
	Greece	11,125,179	284,662	25.6		73,081	6.6		98,872	8.9		303,914	27.3		412,758	37.1		105.5
	Cyprus	766,414	19,574	25.5		186,917	243.9		6,811	8.9		9,182	12.0		47,819	62.4		352.7
	Average				13.0			61.4			8.9			18.7			49.6	
EU-27	**Total**	**493,194,250**	**32,636,495**	**66.2**		**34,791,269**	**70.5**		**4,433,333**	**9.0**		**12,263,212**	**24.9**		**37,701,760**	**76.4**		**247.0**

a) To calculate the food waste per kg/capita we have used the population data of each Member State on page 53 of the BIO report (2011), together with the data on animal and vegetal waste in the agriculture, hunting and forestry sector in each Member State (BIO, 2011: p42) and the data on total food waste generation in the four other sectors (BIO, 2011: p63).
Source: data from BIO (2011), adapted by LEI.

2.1.1 Food losses and waste per commodity group

FAO (2011) estimates lost and wasted food quantities by commodity group for each component of the food supply chain. Table 2.3 presents food losses and waste as a percentage of what enters each sector of the food supply chain of Europe for seven commodities (FAO, 2010: p5).

Table 2.3 **Estimated loss and waste percentages for several commodity groups in sectors of the food supply chain for Europe (including Russia)**

Sector	Cereals	Roots and tubers	Oilseed	Fruit & veg.	Meat	Fish & seafood	Dairy products
Agriculture	2	20	10	20	3.1	9.4	3.5
Postharvest	4	9	1	5	0.7	0.5	0.5
Processing	0.5, 10	15	5	2	5	6	1.2
Wholesale/retail	2	7	1	10	4	9	0.5
Household	25	17	4	19	11	11	7

Source: FAO (2011, p26).

At each stage of the food supply chain, losses and waste were estimated using FAO's Food Balance Sheets from 2009 and results from a thorough literature search on the topic of global food waste. As the table shows, a high percentage of food waste occurs at the household level, according to the FAO, especially for cereals (25%), fruits and vegetables (19%) and roots and tubers (17%). Looking across commodity groups, the highest share of losses for roots and tubers and fruits and vegetables occurs not at the household level, but in the agricultural stage.

Food losses are also high in (primary) agricultural production for fruits and vegetables (20%) and roots and tubers (20%), due to their perishable nature. The largest volumes of food losses occur during agricultural production of roots and tubers (e.g. potatoes). This mainly depends on postharvest crop grading, due to quality standards set by retailers (FAO, 2010: p5). The same is true for fruits and vegetables. Losses of milk in agricultural production can be linked to dairy cow illness (mostly infections), which cause an approximate 3-4% decrease in milk yield.

The relatively low levels of waste with regard to the processing and storage of meat and meat products can be explained by relatively low losses due to animal mortality during breeding and transportation to slaughter.

Buzby and Hyman (2012) have estimated the per capita amount of waste for several, more detailed, commodities at the retail and consumer levels in the United States in 2008 (see Table 2.4 below). The waste for each commodity was estimated by multiplying the quantity of that commodity available for consumption by the appropriate waste assumption. These data presented can be fruitfully compared with the European data available, *the principal reason being the detailed statistical structure with regard to the food-related commodities, for which a more comprehensive analysis of waste then becomes possible.*

Table 2.4 Estimated per capita amount of food waste at the retail and consumer levels in the US, 2008

Estimated per capita amount of food loss at the retail and consumer levels in the United States, 2008.

Commodity	Food supply[a]	Losses from food supply[b]					
		Retail level		Consumer level		Total retail and consumer level	
	Kilograms	Kilograms	Percent	Kilograms	Percent	Kilograms	Percent
Grain products	89.1	10.7	12	15.7	18	26.4	30
Fruit	92.2	8.6	9	13.5	15	22.1	24
Fresh	54.6	6.3	12	9.9	18	16.3	30
Processed	37.6	2.3	6	3.5	9	5.8	15
Vegetables	123.0	10.3	8	24.6	20	34.9	28
Fresh	78.7	7.6	10	17.5	22	25.1	32
Processed	44.3	2.7	6	7.1	16	9.8	22
Dairy products	124.5	14.0	11	20.9	17	34.9	28
Fluid milk	81.2	9.8	12	14.3	>18	24.1	30
Other dairy products	43.2	4.2	10	6.6	15	10.8	25
Meat, poultry, and fish	89.3	4.1	5	30.4	34	34.5	39
Meat	49.1	2.2	4	16.4	33	18.6	38
Poultry	32.9	1.3	4	12.2	37	13.5	41
Fish and seafood	7.2	0.6	8	1.8	25	2.4	33
Eggs	14.5	1.3	9	2.0	14	3.3	23
Tree nuts and peanuts	4.7	0.3	6	0.4	9	0.7	15
Added sweeteners	61.8	6.8	11	11.0	18	17.8	29
Added fats and oils	39.5	8.1	21	5.4	14	13.5	34
Total	638.7	64.0	10	123.9	19	188.0	29

Source: Buzby, J.C. and J. Hyman, 2012. 'Total and per capita value of food loss in the US.' In: *Food Policy* 37: pp. 561-570

2.2 Evidence on the extent to which food losses and waste may be reduced

2.2.1 Introduction

This section considers by how much food losses and waste in the supply food chain can realistically be reduced.

As indicated by Parfitt (2011), among others, the potential for the reduction of food waste in the developed world lies all along the supply chain, up to and

including the consumer at the end point: retailers (supermarkets), food services[1] (or catering industry) and consumers (households).

The figures on quantities of possible food waste reductions are scarce in existing literature, especially at the supply chain level, although there are numerous local initiatives on prevention of food waste in different Member States. The reason for this is that the concept of waste prevention is relatively new and has not yet been implemented into national law by Member States. In addition, food waste prevention initiatives often occur at local level and, given limited budgets, impacts are often not quantified.

Nevertheless, it is possible to review a variety of different strategies to reduce food waste, along with the indicative savings, or market value of the food not wasted, associated with them.

2.2.2 Organisational solutions to reduce food waste

The Italian food distribution sector throws away 238 thousand tonnes of food per year, worth €881m, which could feed 620,000 people a day (Barilla, 2012). Thus in Italy, several supermarket chains have intervened to reduce this food waste. As an example, the Coop Group set up the project 'Buon Fine o Brutti ma Buoni' (Good End or Ugly but Good) to recover unsold food products (due to defects in the packaging or because they are close to expiration), and donate this food to associations and non-profit organisations. In 2010 Buon Fine coordinated collection at 471 points of food sale (equivalent to 63% of the outlets of the nine large cooperatives of the Coop network), working with 1,009 non-profit organisations to save and redistribute more than 2,990 tonnes of food, worth €18m.

The University of Bologna in Italy founded the Last Minute Market (LMM) action-research activity, which later on became a business campaign aiming at the recovery of unsold (or un-marketable) goods for charitable organisations. LMM's activities address the recovery of food products, collection of surpluses from business and manufacturing activities, vegetables that were not harvested and remained in the field and ready-made meals recovered from the food service sector, such as schools and businesses. The actual results obtained by the Last Minute Market are (Barilla, 2012: p90):

- every day, 30 ready meals for the cafeteria are recovered from a hospital in Bologna, for a value of over €35,000 per year;

[1] Food services are businesses and companies responsible for any meal prepared outside the home. This includes restaurants, school and hospital cafeterias, catering operations, etc.

- in Verona, eight tonnes per year of cooked products, amounting to 15,000 meals, were recovered from eight school cafeterias;
- between 2010 and 2011, 43,000 meals were redistributed in the provinces of Bologna and Ravenna;
- Esselunga signed an agreement with the Food Bank Foundation for the collection of food and other surplus: food products were recovered for a value of €1m in 2009 (Barilla, 2012: p94).

2.2.3 Technological solutions to reduce food waste in retail

To prevent food losses at the retail level, two UK retailers (Tesco and Marks & Spencer), are both testing the use of an ethylene-absorbing strip to prolong produce life. The strip uses a mixture of high-tech minerals and clay to absorb ethylene, the hormone that causes fruit to ripen and turn moldy, and the product is 100 times more effective than any competing materials. The retailers estimate it could save 1.6m packs of tomatoes, 350,000 packs of avocados, and 40,000 packs of strawberries (Gunders, 2012). Marks & Spencer use the strip inside its strawberry punnets. The strip extends fruit life by two days and makes the fruit taste just as good on day six as on day one. The result is a minimum waste reduction of 4% (Environmental Leader, 2012).

2.2.4 Informational solutions to reduce food waste

Musgrave Group/United Biscuits in the UK improved forecasting for promotional items and reduced promotional waste by 13%, and Warburtons in the UK removed 'display until' dates from its bread product packaging to reduce consumer confusion (Gunders, 2012).

2.2.5 Reduction of food waste in the food service sector

Marthinsen et al. (2012), in their study 'Prevention of food waste in hospitality sectors (restaurants, hotels, canteens and catering)', focus on Nordic countries, and conclude that it is difficult to specify a best estimate of the quantities of avoidable food waste from the hospitality sector in the Nordic countries. This is due to the following reasons:

- there are great variations in the estimates (because of differences of sampling and aggregation protocols, as stated previously);
- studies include different parts of the total food waste generated;

- many of the national reports only include data from a specific part of the hospitality sector.

The authors suggest that the estimates with reference to EUROSTAT data are the best available overall statistics. The uncertainty in the estimates is, however, significant and it includes food waste that is avoidable and that is unavoidable. Using the average rate for avoidable food waste for the profit sector of 67% (based on study of WRAP), the authors calculated the total avoidable food waste in Nordic countries in the hospitality sector (Table 2.5).

Table 2.5 **Best estimate of total food waste and avoidable food waste in Nordic countries**

Country	Total food waste (in tonnes/year)	Avoidable food waste (in tonnes/year)
Denmark	140,000	94,000
Finland	140,000	94,000
Norway	140,000	94,000
Sweden	260,000	174,000
Total	680,000	456,000

Source: Marthinsen et al. (2012): 54 (Table 15).

The figures in Table 2.5 correspond fairly well with the figures in Table 2.2a for the countries involved. When applying that same average rate for avoidable food waste of 67% of total food waste across the EU27, the total avoidable food waste in food service and catering will be 8.2m tonnes. But the applicability of such an average conceals regional and national differences, as is evident from Tables 2.2a and 2.2b, which may be very important to take into account when formulating corrective waste prevention policies and programmes.

According to SRA (2010) an average restaurant in the UK can reduce its food waste by 20%. The food waste mostly comes from preparation (namely 65%), from customers' plates (30%) and from out-of-date or unusable items (5%). That generates an average annual reduction of over 4 tonnes of food waste per restaurant, more than UKP2,000, from avoided food costs (by from using food that would normally have been thrown away), and between UKP150-1,700 on waste collection costs if food is collected for anaerobic digestion (SRA, 2010).

2.2.6 Reduction of households food waste

In 2008 the 'Love Food, Hate Waste' campaign[1] was launched in the UK and run by the government-funded Waste and Resources Action Programme (WRAP). In January 2009 the campaign claimed to have helped almost 2m households reduce their food waste, amounting to savings of almost UKP300m and stopping 137,000 tonnes of waste going in the bin, according to WRAP[2] (BIO, 2012b: p121). So the campaign achieved a nearly 3% reduction in avoidable household food waste (or 1.8% of total food waste) throughout the UK over a one-year period (BIO, 2011: p152).

The cost structure for the Love Food Hate Waste campaign consisted of approximately UKP600,000 (€705,000) in initial research to identify sources and causes of food waste, enabling an effective targeting of communication efforts. Ongoing running costs total approximately UKP2m (€2.4m) per year, including advertising, public relations, events, website maintenance and the production of new communication materials (BIO, 2011: p153).

About 45 to 49% of consumers in the UK misunderstand the meaning of the date labels 'best before' and 'use by' on food products. Food waste resulting from date label confusion accounts for up to 1m tonnes of food waste, approximately one fifth of the avoidable food waste produced by households in the UK (BIO, 2011: p142). The financial savings for households from throwing away less food were estimated by WRAP as UKP12bn (€14bn) per year in the UK, or an average UKP199 (€233) per person per year, by calculating the value of the avoidable fraction of food waste. Using the estimated 1m tonnes of food waste triggered by date labelling confusion, representing approximately 20% of avoidable food waste generated in the UK, potential savings to consumers can be estimated at up to UKP39.80 (€46.60) per person (BIO, 2011: p144). Date labelling coherence is anticipated to have the possibility to reduce generation of avoidable food waste in the household sector by up to 20% (BIO, 2011: p159). In comparison, people in the US, on average, throw away 20 pounds of food each month, which amounts to an annual loss of USD1,350 and USD2,275 for the average family of four (Gunders, 2012: p12).

[1] See http://www.lovefoodhatewaste.com.

[2] See also http://www.edie.net/news/news_story.asp?id=15861&channel=0.

2.2.7 Adaptations to legislation and regulations

Adaptations to legislation and regulations can significantly reduce food waste in two areas. First, by introducing compulsory best before dates for non-perishable products and by introducing a compulsory long expiration term for long-life products (Waarts et al., 2011: p73). Second, by extending the time that unpackaged food products intended for direct consumption may be exposed to the outside temperature (currently not more than two hours) in the catering sector would directly result in less food being thrown away (Waarts et al., 2011: p9). Adapting legislation in order to reduce food waste has a greater effect when social and economic interests are taken into account (Waarts et al., 2011: p10).

2.2.8 Food waste reduction public policy targets

The Nordic countries and the Netherlands have set reduction targets in the short to medium term at a level that, if replicated in all high-income countries, would make the 50% food waste reduction target possible before 2050 in those countries. In Sweden a 20% food waste reduction target for 2020 was suggested, but this was not accepted by the government. This will be proposed again as part of their National Waste Prevention Programme to be delivered later this year. In the case of the Netherlands an intermediate target of 20% has been set for 2015.

For the UK a medium-term aspiration of a 10 to 15% reduction by 2015 would be quite achievable and give direction to voluntary agreements and have an impact on food waste from consumers (Foresight, 2011: 14).

France already has announced its 50% reduction goal of the volume of food waste by 2025, and furthermore proposes a national pact against food waste, signed by a wide range of leading stakeholders to signal their shared commitment.

In a recent press release, the Austrian Environment Ministry[1] has proposed a 20% food waste reduction target for 2016, but no baseline year has yet been stated.

Sweden's national goal for 2010 was that 35% of the food wastes from households, restaurants, large scale kitchens and shops shall be treated by biological methods such as composting and fermentation. This is not food waste prevention but a way to make better use of the food waste. The goal will proba-

[1] See: www.lebensministerium.at

bly be updated to 45% in 2015 and with the clarification that the waste should be treated so the plant nutrients are utilised (Stenmarck et al., 2011: p15).

2.3 Evidence on costs of reducing food losses and waste

Concerning costs of reducing food waste, there are no references to the *actual costs associated with reducing food waste per se*. The studies we found only consider the cost embodied in the food waste itself or only estimate what is the value to the economy per year. For example, the Swedish Environmental Protection Agency estimates1 that a 20% reduction of amounts of food waste in Sweden would result in €1 to 1.7bn of economic benefit. Another study by Milieu Centraal, concerning food waste in the Netherlands, estimated that each person throws away €155 in average per year.

According to the Centraal Bureau Levensmiddelenhandel in the Netherlands, 50% less food will be wasted in supermarkets and food service companies in the Netherlands when national regulation with regard to unrefrigerated perishable food products (such as sausage rolls, cheese croissants, cold meats, cheese) becomes less stringent. That would provide a saving of €25m per year in the value of food not wasted before purchase (CBL, 2012).

2.4 Literature review on impacts

2.4.1 What are impacts?

While the literature on the evidence on food losses and/or waste is expanding, there is surprisingly little known on the potential impacts of food losses and/or waste, and the impacts of reducing them. The literature at most estimates what food loss and/or waste imply on the input side in terms of resources used and so wasted (e.g. land and water used) and on the output side in terms of outputs that are lost or wasted (e.g. in terms of food production, consumption and sometimes nutrition) and implied negative external effects (e.g. greenhouse gas emissions).

Estimates for the US, for example, suggest that food waste corresponds to 40 trillion litres of irrigation water, enough water to meet the household needs of 500m people (Lundqvist et al., 2008). Similarly, McKinsey (2011) estimates

[1] Calculation by Swedish EPA May 2012.

that reducing food waste at the consumer level by 30% could save roughly 100m acres of cropland by 2030. Cutting in half the total amount of food losses is also said to contribute the equivalent of 25% of today's global food production to the total food supply (Lundqvist et al., 2008). And, roughly one third of food produced for human consumption that is lost or wasted globally every year (FAO, 2011) is estimated to be equivalent to 6 to 10% of human-generated greenhouse gas emissions (Vermeulen et al., 2012).

When it comes to calculating environmental impacts, most studies take a quite comprehensive approach and estimate so-called footprints that measure the various ways resources are used or needed or external impacts generated throughout the lifecycle in terms of a single unit of measure. Examples are the carbon footprint in terms of emissions, the ecological footprint in terms of land surface implied and the water footprint reflecting virtual water content (BCFN, 2012). In April 2013 the FAO will publish the FAO's Global Food Wastage Footprint, the first global quantification of the environmental impacts of food waste, and this will shed further light on this area.

When it comes to calculating economic impacts of food losses and/or waste, similar approaches are taken, including estimating the value that is lost with food losses and/or waste, the price of the foods lost and/or wasted, the willingness to pay the price of the environmental impact associated with losses and/or waste, or the opportunity cost of the agricultural surface used to produce the lost and/or wasted foods, or a combination of these (BCFN, 2012).

Whilst useful for knowing the scale of the problem, translating food waste and/or losses one-to-one in terms of (value of) input use or (value of) outputs involved is not the same as calculating impacts; such an approach ignores interactions between demand and supply and the role of the price mechanism therein, and more generally interactions between actors and sectors in the food system and in the wider economy. Given the scale of the problem, these second-order effects could be quite considerable. For example, reducing food losses on the supply side (food waste on the demand side) could lower food prices quite considerably, leading to a change in demand (supply) of food so that the resulting impact is likely to differ from the value of resources or output embodied in the losses (waste) itself.

This study defines impacts of reducing food losses and/or waste in the EU as the consequent changes that may occur in demand and supply, prices and incomes, taking into account the behaviour of the various actors (consumers, producers and government) in the various sectors and markets of the wider economy and in a global context.

2.4.2 Impacts on food security, prices and incomes

The literature that, so far, has primarily focused on collecting data on the causes and extent of food losses and food waste, and on policy options to reduce these, in between the lines make suggestions on economic impacts. The essence of the message is that food security[1] is expected to be negatively affected by food losses and/or food waste and that food prices are likely to be much higher and incomes are likely to be much lower as a result of it. Vice versa, if one were to combat food losses and/or waste, this is expected to benefit food security, through lower prices and higher incomes. These concerns are mostly voiced with respect to the poor and vulnerable in developing countries, where negative income effects and high prices may contribute to food insecurity of net food consumers. Similarly, net producers in developing countries may be negatively affected if food prices fall and so their incomes are lower. Impacts on food consumption, food prices and incomes (of food producers), are nonetheless also felt within the EU.

Two citations dealing with impacts of food losses and/or waste that we could explicitly find in the literature illustrate the main line of reasoning:

'For the producer, income is reduced, while for the consumer it means higher than necessary spending on food' (Lundqvist et al., 2008; p26). The former seems to refer to the impact of food losses in production and the latter to the impact of food waste in consumption.

> 'Economically avoidable food losses have a direct and negative impact on the income of both farmers and consumers. Given that many smallholders live on the margins of food insecurity, a reduction in food losses could have an immediate and significant impact on their livelihoods. For poor consumers (food insecure or at-risk households), the priority is clearly to have access to food products that are nutritious, safe and affordable. It is important to note that food insecurity is often more a question of access (purchasing power and prices of food) than a supply problem. Improving the efficiency of the food supply chain could help to bring down the cost of food to the consumer and thus increase access. Given the magnitude of food losses, making profitable investments in reducing losses could be one way of reducing the cost of food. But that

[1] Food security is most commonly defined as '…when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life' (FAO, 1996).

would, of course, require that financial gains from reduced losses are not outweighed by their costs.' (FAO, 2011; p1).

Here it is suggested that both incomes of producers and consumers will be negatively affected by food losses (not waste). But further on, with respect to consumers, the focus shifts to the cost of food to the consumer, i.e. the price (fifth and last sentence) affecting the purchasing power through real incomes and, perhaps, the cost of food waste itself (expenditures on which reduce expenditures on other commodities or savings).[1]

Combining these observations suggests that reducing food losses in supply and food waste in demand could relieve part of the pressures and enhance food security of especially the poor and vulnerable. First, it would increase food available for consumption at lower prices for households. Second, it would reduce production costs and increase sales (and incomes) for producers.

Lower prices, while beneficial to net food consumers, are harmful to net food producers. Producers may actually lose out from reductions in waste in consumption as sales and prices, and so incomes, are likely to be negatively affected. It is also doubtful whether reducing food losses and notably waste in medium- and high-income countries would help the poor and vulnerable in low-income countries, or countries in general where food insecurity is an issue. Food availability on the world market may increase which lowers world prices and could benefit net food consumers (or importers) but harm net food producers (or exporters) in the developing world. This depends however on the trade/local content of foods consumed in developing countries and whether or not tariff or non-tariff barriers to trade exists which may prevent the free movement of food commodities altogether. Generally, as indicated in the last sentence of the second citation, costs may be involved in reducing food losses and/or waste, undoing the potentially beneficial impacts of reducing it and which may motivate the existence of food losses and/or waste in the first place.[2] Finally, lower food prices could encourage waste as it is cheap[3] and/or enhance re-

[1] This is confirmed by an applied study on meat consumption by Westhoek et al. (2011), briefly looking at the issue of food waste as well. This study finds that a reduction of food waste of 15% reduces agricultural prices by about 4% which generates an increase in food consumption.

[2] While some measures to reduce food losses and/or waste may be costless (e.g. behavioural change on the part of consumers or producers), others may involve quite significant costs (e.g. investments in storage facilities on the supply side), but consistent global data on costs are hard to find.

[3] See, for example, BCFN (2012; p34 and 54).

source inefficient (e.g. meat) consumption via lower (feed) prices. It could also encourage the use of biofuels.[1]

These issues are best investigated empirically, using an applied model encompassing the whole economy, including the food supply chain from farm to fork.

2.4.3 Land use and environmental impacts

A reduction of food waste in demand implies less demand for agricultural commodities and therefore less demand for land. As a result, the environmental impacts of food production are expected to be lower, except for when the environmental impacts of instruments to reduce food waste are worse than the effect of the reduction in production as a consequence of the reduction in food waste. This is an empirical question.

Similarly, a reduction of food losses in supply will normally generate a reduction in land use and environmental impacts of land use and land use change. When the measures to reduce waste in production require more environmentally damaging activities than the production of extra food, the net effect can theoretically be negative, but does not seem very plausible. Secondary impacts on land use and the environment could result from increased meat and biofuel consumption following lower prices for agri-food commodities if food waste reduction reduces production cost per unit of food consumed.

There is one study that looks at the land use and environmental impacts of waste reduction in the global consumption of food, which is the study by Westhoek et al. (2011). This study finds that a reduction of food waste of 15% would reduce the agricultural area by about 250m hectares (4.5% of land area) and, as a consequence, an increase of 8% of greenhouse gas emissions between 2000 and 2020 instead of an increase of 25% during this period. The effect on greenhouse gas emissions is much stronger than the change in area suggests, since the changes in agricultural area imply deforestation and therefore a loss in carbon stock and biodiversity.

[1] This is found by the study of Westhoek et al. (2011). The most commonly used definition of the FAO (2011) would label food use by biofuels or other secondary uses as a loss, if it was originally intended for final consumption by households. This is subject to debate as one can also argue that this alternative use generates an economic value and thus is not lost.

2.5 Summary of main findings

The literature reviewed on the evidence of food losses and food waste provides some amounts and percentages regarding current food loss and waste in agriculture, processing, distribution, retail, food service and households within the EU27 or at the Member State level. Issues with the robustness of available data on food waste in the EU27 exist due to inconsistent definitions of food waste and methodologies for calculations.

The causes of food loss and waste are, nevertheless, widely described in literature. Numerous initiatives for food loss and waste prevention and reduction are set across different Member States in the EU. Food loss and waste prevention initiatives are often taken at a local level and there is a lack of information regarding the level of impact actually achieved and costs involved. We thus proceed by using the 2020 target of 50% reduction in food waste as an 'ambitious' target (see Chapter 4) in the modelling, along with a 40% reduction as a 'realistic' target and 30% as a 'moderate' target.

The data available determine the type of investigation that can be made through the modelling. The Eurostat data allow us to analyse waste by EU27 countries, but not by specific groups of food-related commodities. The FAO data allow us to analyse waste only for the EU27 as a whole (no disaggregation possible), using data for Europe plus Russia, but with regard to 7 food-related commodity groups: Cereals, Roots and tubers, Oilseeds and pulses, Fruit & veg, Meat, Fish and seafood, Milk and dairy produce. The FAO (2011) data for Europe, available at a more detailed commodity level than the other statistical references to food loss and waste within the EU, are taken as the point of departure for the modelling of the impacts of reductions in food losses and food waste.

The current literature considering impacts of food losses and/or food waste is very limited and focuses on the (value of) input use or (value of) outputs involved. We concur that this is not the same as calculating impacts as it ignores interactions between demand and supply and the role of the price mechanism therein, and more generally interactions between actors and sectors in the food system and in the wider economy. We define impacts of reducing food losses and/or waste in the EU27 as the consequent changes that may occur in demand and supply, prices and incomes, taking into account the behaviour of the various actors (consumers, producers and government) in the various sectors and markets of the wider economy and in a global context.

The predominantly qualitative literature suggests that combatting food losses/and or waste benefits food security, through lower prices and higher in-

comes. Reducing food losses and/or food waste would, first, increase food available for consumption at lower prices for households and, second, it would reduce production costs and increase sales (and incomes) for producers. These rather bold statements do not acknowledge the inherent differences between food waste (operating on the demand side) and food losses (operating on the supply side) which may have distinctly different impacts on prices and trade quantities. It also does not consider how costs may affect outcomes, and does not take into account the influence of trade. We find that these issues are best investigated empirically, using an applied model encompassing the global economy and the food system in particular.

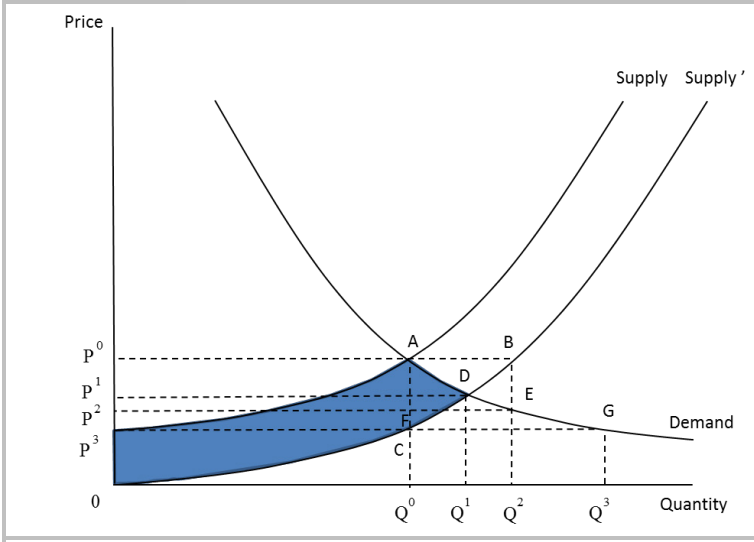
3 Lessons from Economic Theory: A Graphical Exposition

Economic theory may be able to tell us more about expected economic impacts and may guide the interpretation of the outcomes of a more complex empirical model with added real life complexities. The analysis discusses potential economic impacts of reducing food losses in supply, reducing food waste in demand, and ending with a discussion of the results. The methodology used is standard economic theory of demand and supply, by which one may analyse what happens in the market for one food commodity. On the basis of this analysis we may draw conclusions on what may happen if the analysis is further complicated and extended to the broader economy. It is in its entirety based on Rutten (2013). Presented here is a reduced version of this article. It forms the basis of the applied modelling in Chapters 4 and 5, which can distinguish different types of food commodities and their interrelations in the food supply chain from farm to fork and within the broader (global) economy.

3.1 Reducing food losses in supply

Figure 3.1 depicts the market for a food commodity, with a standard upward sloping supply curve and a standard downward sloping demand curve. The price mechanism ensures that demand equals supply. The equilibrium is reached at point A, where the price is P^0 and the quantity traded is Q^0.

Figure 3.1 **Impacts of reducing food losses in supply**



Source: Rutten (2013).

Let us assume that there are losses in the production and supply of this food commodity. In such a situation, the socially optimal supply curve, or the supply curve of this food commodity that would not have these losses, lies below the original supply curve, as depicted by $Supply'$ in Figure 3.1; given the original price, P^0, more can actually be produced and supplied to the market (Q^2 at point B), or the original quantity, Q^0, can actually be produced at a much lower cost (P^3 at point C) if losses were to be absent.[1]

Avoiding these losses, given the original demand curve, would thus result in a lower price, P^1, and a higher equilibrium quantity, Q^1, in the market, as given by point D. At this new equilibrium consumers can buy more food at a lower price, resulting in a welfare gain to consumers as measured by the change in the consumers surplus of P^0ADP^1. Similarly, producers can sell more, but at a lower price, resulting in a change in the producer surplus of $P^1D0 - P^0AP^3$, which is also positive. The overall welfare gain equals the sum of the change in the producer and the consumer surplus, which amounts to the area P^3AD0, the blue shaded area between the new and old supply curve and under the demand curve.

[1] Note that the 'optimal' supply curve does not necessarily have to be parallel to the original supply curve, as the extent of losses may vary with the scale of production (and price). We abstract from this for ease of exposition.

The outcome and so the size of the welfare effects depends on the slope of the demand and supply curves (i.e. the elasticity of demand and supply curves). In this simple, low-dimension diagrammatic analysis, overall welfare, and specifically the welfare of consumers, generally goes up, whereas that of producers could go down, namely in the case of supply being relatively inelastic.[1] This is an interesting finding as it suggests that producers of food commodities such as crops, which in the short run have a relatively inelastic supply curve given the time it takes before they are ready to be harvested, may be worse off in the short run when tackling food losses. In the long run, the supply of agri-food commodities is almost perfectly elastic, so then welfare gains are likely to occur (and most, if not all, of these end up with the consumer).[2]

We have, however, made various simplifying assumptions to come to our findings. First, we assume throughout the analysis that all losses in the production and supply of this food commodity are avoidable, that they are independent of scale (and price) and that they are costless to diminish. In reality this may well be different so that the outcomes may differ. Specifically, the impacts may be much smaller if only a part of the food losses is avoidable, and the net welfare gains will be lower if there are costs involved. These costs will have a price-increasing and quantity-reducing effect in the market for the food commodity in question, undoing the original shift down (or to the right) that occurs when reducing food losses in supply. Moreover, if losses increase with scale (and price), the observed impacts of reducing food losses will be greater if the market is of a reasonable size (i.e. the quantity demanded and supplied is large) and the price is high; and, vice versa, if losses decrease with scale (and price), impacts of reducing losses will be bigger if the market is small and the price is low.[3]

Another simplification is that we ignore where the losses occur in the supply chain (intermediate inputs, factor inputs), and that we abstract from interactions with oth er markets and actors. Our analysis makes the usual *ceteris paribus* assumption, i.e. that all else remains the same, which is highly unlikely. For example, reducing losses generally results in a lower price, which could increase demand elsewhere in the system, potentially leading to second-order effects. An example is wheat becoming cheaper if losses in production and supply fall, as a result of which meat demand may go up (as meat will become cheaper to pro-

[1] This has been analysed more extensively in Rutten (2013).

[2] This finding suggests the importance of inter-temporal effects, not addressed in this simple low-dimension partial equilibrium framework.

[3] Note that in the former (latter) situation, the supply curve with and without losses would increasingly diverge from one another as the quantity and price increases (decreases).

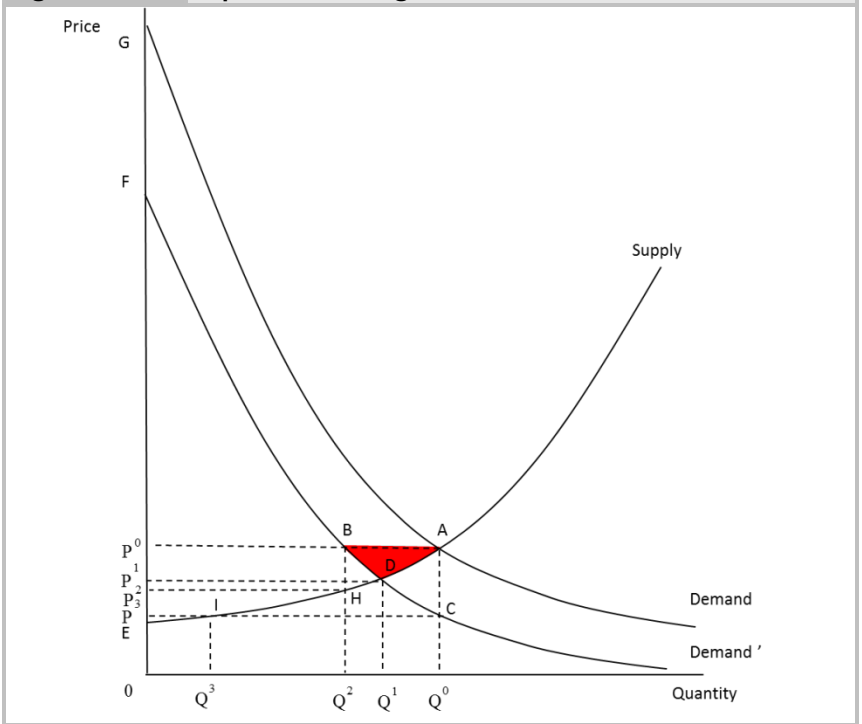
duce due to lower intermediate input costs of using wheat). Similarly biofuel use may go up. Another example is that households may waste more if food becomes cheaper, undoing the positive impact of reducing food losses on the supply side.[1] What exactly will happen remains an empirical question and is best investigated in an applied model of the whole economy with added real-life complexities. Nevertheless, these effects will still operate in the background and thus give a useful guide to the interpretation of the outcomes of such a model.

3.2 Reducing food waste in demand

Figure 3.2 depicts the market for a food commodity, again with a standard upward sloping supply curve and a standard downward sloping demand curve and the equilibrium at point A, where the price is P^0 and the quantity traded is Q^0.

[1] Of course, consumers under pressure from prevailing morale may also display the opposite behaviour and reduce food waste. This is the topic of the next section.

Figure 3.2 **Impacts of reducing food waste in demand**



Source: Rutten (2013).

Let us assume that there are losses in the consumption of this food commodity, in that consumers waste part of what they demand. In such a situation, the socially optimal demand curve, or the demand curve that would not have these losses, lies to the left of the original demand curve, as depicted by $Demand\ '$ in Figure 3.2; given the original price, P^0, less needs to be consumed (Q^2 at point B) so as to reach a certain level of utility if waste was to be absent, or the original quantity, Q^0, represents a much lower value to the consumer (P^3 at point C).[1]

Avoiding waste in consumption, given the original supply curve, would thus result in a lower price, P^1, and a lower equilibrium quantity, Q^1, in the market, as given by point D. Since producers are able to sell less and at a lower price,

[1] Equivalent to the analysis on the supply side, the 'optimal' demand curve does not need to lie parallel to the original demand curve as the extent of waste in demand may vary with scale and price. We abstract from this for ease of exposition.

their welfare is negatively affected as shown by a change in the producer surplus of $P^1DE - P^0AE = -P^1DAP^0$. Taking the difference between the area under the new and old demand curve and above the new and old price respectively, $P^1DF - P^0AG$, would result in a change in the consumer surplus of $P^1DBP^0 - BAGF$, the sign of which is ambiguous depending on the size of the shock on demand and price.[1] This would ignore, however, the fact the old demand curve encompasses waste, so that consumers only realise P^0BF in value when consuming Q^0 of the food commodity at a price P^0; the remainder, $BAGF$, is lost due to wastage. The change in the consumer surplus if waste is avoided thus amounts to $P^1DF - P^0BF = P^1DBP^0$, which is now positive. The overall change in welfare that results equals $P^1DBP^0 - P^1DAP^0 = -BDA$, the red shaded area in Figure 3.2, which is negative.[2]

To conclude that the overall welfare impacts of reducing wastage in demand would be negative is wrong since the analysis is still not complete. The question that remains is what consumers would do with the saved expenses on this particular food commodity, $P^0Q^0 - P^1Q^1$. Consumers may want to add this amount to savings, in which case it could be used for consumption in future with associated utility gains or investments with a rate of return. Or, consumers may want to spend it now on the consumption of other commodities, and perhaps food. In this case it would lead to a shift in the demand curve(s) of the respective commodity or commodities in the opposite direction of that depicted in Figure 3.2, i.e. a shift to the right, leading to a higher price and quantity in the accompanying market(s) and a welfare gain in this (these) market(s) for producers in terms of an increase in the producer surplus, and a potential welfare gain for consumers if the change in the consumer surplus is positive. The overall welfare change(s) in this (these) respective market(s) would be positive and equivalent to the difference between the new and old demand curves and above the supply curve (if one were to take the example of Figure 3.2, $DAGF$).

The overall welfare impacts in the market of the food commodity in which waste is reduced and other markets combined depends on consumer preferences. Nonetheless, the welfare loss for producers, that occurs due to waste reduction by consumers of the food commodity in question and arises due to a

[1] In Figure 3.2 the effect seems to be negative.

[2] Note that if one, mistakenly, were to include the area $BAGF$, the overall welfare loss would amount to $DAGF$, the difference between the two demand curves and above the supply curve, which is analogous to the result of the analysis of loss reductions on the supply side. The analysis on the demand side differs from that on the supply side in that the original demand curve *includes* wastage, i.e. represents *gross* demand, whereas the original supply curve is the supply that would result *after* losses, i.e. it represents *net* supply.

fall in the price of the food commodity in question, is highly likely to be counteracted by welfare gains for producers and consumers in other markets.[1]

As before, the outcome and so the size of the welfare effects depends on the slope of the demand and supply curves. In this simple, low-dimension diagrammatic analysis of reducing waste in demand, consumer welfare generally goes up or at best remains the same, whereas producer welfare falls or at best remains the same, resulting in an overall welfare impact ranging from negative to, at best, zero in the long term when the supply of agri-food commodities is almost perfectly elastic.[2] As indicated before, the analysis excludes interactions with other markets. Welfare gains to producers and consumers in other markets will result if consumers decide to spend the saved expenditures on other commodities.

We have also made various other simplifying assumptions to come to our findings. First, we assume throughout the analysis that all waste in the consumption of this food commodity is avoidable, that it is independent of scale (and price) and that it is costless to diminish. In reality this may not be the case and, hence, the outcomes may differ. Specifically, the impacts may be much smaller if only a part of the food waste is avoidable, and the net welfare gains will be lower if there are costs involved to the consumer. These costs will counteract the original shift down (or to the left) that occurs when reducing food waste in demand. Moreover, if waste increases with the amount consumed and decrease with price, the observed impacts of reducing food waste will be greater if the market is of reasonable size (i.e. the quantity traded is high and the price is low) and vice versa if waste decreases with scale of demand and increases with price, impacts of reducing losses will be bigger if the market is small.[3]

Our analysis generally makes the usual *ceteris paribus* assumption, i.e. that all else remains the same, which is highly unlikely. Again, what exactly will happen remains an empirical question and is best investigated in an applied model of the whole economy with added real-life complexities. Nevertheless, these ef-

[1] This is the second notable difference with the analysis of loss reductions on the supply side. Specifically, the loss reduction on the supply side is assumed to benefit the commodity in question in terms of lower costs of producing the same amount of good and/or increased outputs given costs. On the demand side however, it is almost more relevant to know what happens in other markets depending on consumer preferences and following consumer decisions on what to do with the saved expenses on the commodity that previously had wastage.

[2] For a more elaborate analysis see Rutten (2013).

[3] Note that in the former (latter) situation, the demand curves with and without waste would increasingly diverge from one another as the quantity increases (decreases) and the price decreases (increases).

fects will still operate in the background and thus give a useful guide to the interpretation of the outcomes of such a model.

3.3 Discussion of results

What has become evident from economic theory is that the impacts of tackling food losses in supply and food waste in demand in terms of quantity are different from the original size of the food losses and waste, and depend crucially on the extent of the food losses and/or waste relative to the size of the market, the extent to which they are avoidable, factors that cause them to arise in the first place (notably the level of food prices), the costs associated with measures to reduce them and interactions within the food supply chain and with other actors and markets. Impacts also vary with the slope of the demand and supply curves and consumer preferences play an important role on the demand side.

Regarding the costs of reducing food losses and waste, the literature remains surprisingly silent. Whereas some measures to reduce food losses on the supply side, such as improved harvesting techniques by farmers or other behavioural changes (also by other actors in the supply chain), may cost relatively little, other measures, such as investments in storage facilities and improved transport (including cold chain), may cost much more. Consistent data on costs of measures to tackle food losses are hard to find, not the least because they are likely to vary with the food commodity in question, the segment of the food supply chain, and by country due to differences in, for example, the level of development, location and climatic conditions. Although behavioural change on the part of consumers to waste less food may directly cost relatively little, it may require consumers, for example, to go more often to the supermarket to buy fresh food that is better adjusted to their needs and wants, which involves time and effort. In other words the perceived or indirect cost by the consumer may still be high.

Regarding the factors causing food losses and/or waste, relatively low food prices are said to be an important cause (e.g. BCFN, 2012). It may thus well be that from the perspective of costs and benefits it is better for agri-food producers and suppliers to allow for some food losses (at a relatively low cost) rather than to take measures (at a relatively high cost and low returns) to combat them. Similarly, for consumers the relatively low cost of food may prevent her from taking action. Future research should quantify the relationship between food losses and/or waste and food prices.

If one takes all these factors into account, one cannot be certain a priori what the impacts will be, notably when it comes to food security and welfare. Trade-offs are shown to occur with winners and losers, most visibly on the demand side where a reallocation of spending away from previously wasted food towards other products or commodities (and perhaps food) causes some producers to be worse off and some to be better off. Trade-offs also arise over time, as in the short run, producers may have to incur costs and/or welfare losses when food losses are tackled with gains in terms of increased revenues, if any, occurring later, and consumers may delay spending savings on previously wasted foods due to market uncertainty and increased costs of living.

The analysis becomes much more complicated if food waste in demand and food losses in supply would change simultaneously, possibly in reaction to one another, and on a global scale. What exactly will happen remains an empirical question and is best investigated using an applied model. The following chapter discusses analyses the economy-wide impacts of reducing food waste in demand using the global economic simulation model, MAGNET.

4 The MAGNET model

This chapter describes the MAGNET (Modular Applied GeNeral Equilibrium Tool) model that has been used to analyse the impacts of reducing food waste in demand (retail and household consumption) in the EU. The first section gives a description of 2007 data used and the choice of aggregation, i.e. regions, sectors and production factors, for which MAGNET will produce results. Section two provides a description of the behaviour of actors and markets in the countries under consideration, commencing from the standard GTAP core model to which modules have been added to suit the topic of (reducing) food waste. The third section discusses the scenarios that will be implemented, including a baseline scenario reflecting the 'Business as Usual', various Food Waste scenarios that focus on reducing food waste in demand (by commodity grouping and in total, and ambition level) and a Healthy Diet scenario focusing on dietary change towards a more healthy consumption pattern. The final sections present the indicators that will be shown when discussing the results, based on what MAGNET can produce in terms of outputs, and discusses delimitations of the modelling exercise.

4.1 Data and aggregation

4.1.1 Data

For the purpose of this project, MAGNET has been calibrated using the most recent GTAP database version 8 (final release), which contains data for 2007 and reflects all policy changes up to this year.[1] The database is fully documented and contains comprehensive and consistent data on production, consumption and trade between countries in the world. The standard GTAP database contains 129 countries/regions and 57 sectors (i.e. commodities).

4.1.2 Model aggregation

It is common to group the GTAP countries and sectors into more manageable categories. This is done for the purpose of focusing on the sectors and coun-

[1] Available from: https://www.gtap.agecon.purdue.edu/databases/v8/

tries of interest for the research question (known as 'flexible aggregation'), and so as not to slow down the model when running the simulations required for scenario analysis. For the purpose of this project, an aggregation has been made consisting of eight regions, twenty sectors, and five factors of production (Table 4.1).

The EU as main region of interest is identified separately.[1] The remaining countries and regions are grouped into main geographical blocks, including Sub-Saharan Africa (SSA) as the main region of interest from the point of view of food security.

With respect to the sectoral division, and keeping in mind the sectors for which food waste and/or loss information is available, the main agri-food commodities are separated out. This includes both the primary agricultural commodities, as well as the associated processed categories which processes the commodities further into final consumer goods. Specifically, the first eight sectors in Table 4.1 cover agricultural, i.e. land-using sectors, consisting of food-related crops (cereals, vegetables and fruits, oil seeds, and sugar cane and beet), livestock and livestock produce (cattle, chicken, raw milk) and other non-food related agricultural produce. Fishing is another primary sector that is included. The following rows contain processed food categories, including red meat products, white meat products, vegetable oils, dairy products, processed rice, sugar (raw sugar, molasses and other sweeteners) and other food, beverage and tobacco products (from here on referred to as 'other food'), with strong linkages to the primary agricultural sectors. A manufacturing sector comprises all industries, excluding processed food sectors. With respect to services, a retail sector is distinguished, which covers retail and whole sale trade, as well as hotels and restaurants, through which a lot of food is indirectly being consumed (this sector is from here on shortened as 'retail'). The remaining services have been grouped together. The chosen sector/commodity aggregation allows for a complete analysis of the impacts of reducing food waste and/or losses for a wide variety of food commodities and along the various components of the supply chain, including primary (agricultural) production, processing food industries, and retail and final household consumption.

The model retains the standard GTAP specification of five factors of production, including skilled and unskilled labour, capital, land and natural resources. The latter category comprises all resources used in the production of goods,

[1] Since data on food losses and/or waste by commodity group are at best available for Europe (see FAO, 2011), we did not further subdivide the EU in countries and/or regions.

excluding labour, capital and land. It thereby includes water, and also minerals, for example.[1]

Table 4.1 Choice of regions, sectors and factors a)

Regions		**Sectors**	
EU27	EU27	CER	Cereals: paddy rice, wheat and other cereal grains
ROE	Rest of Europe	v_f	Vegetables and fruits
NAM	North America	osd	Oil seeds
CSA	Central and South America	c_b	Sugar cane, sugar beet
ASIA	Asia	ctl	Cattle, sheep, goats, horses
OCE	Oceania	chk	Chicken: other animal products, incl. poultry, eggs, swine,…
MENA	Middle East and North Africa	rmk	Raw milk
SSA	Sub-Saharan Africa	OAG	Other agriculture: other non-food related crops and animal produce
		fsh	Fishing
		rmt	Red meat: cattle meat products
		wmt	White meat: other meat products
Factors		vol	Vegetable oils
Land	Land	mil	Dairy products
UnS-kLab	Unskilled labour	pcr	Processed rice
SkLab	Skilled labour	sgr	Sugar: raw sugar, molasses and other sweeteners
Capital	Capital	FBT	Other food, beverage and tobacco products
NatRes	Natural resources	MNF	Manufacturing, excl. processed foods
		ret	Retail, wholesale, hotels and restaurants
		SVC	Other services

a) Abbreviations with small letters are sectors available in the GTAP database. Abbreviations with capital letters represent an aggregation of a number of GTAP countries or sectors.

[1] The GTAP community is currently working on improving the representation of water as a separate resource used in production, but the results of this effort are not available as yet.

4.2 Behaviour of actors and markets

MAGNET (Modular Applied GeNeral Equilibrium Tool, release version 2) is a multi-region Computable General Equilibrium (CGE) model that has been widely used to simulate the impacts of agricultural, trade, land and biofuel policies on global economic development (Woltjer et al., 2013). MAGNET is based on the Global Trade Analysis Project (GTAP) model but can be extended in various directions in a modular fashion, depending on the policy questions at hand.

4.2.1 The GTAP core

The GTAP core model accounts for the behaviour of households, firms and the government in the global economy and how they interact in markets (Hertel, 2007). A non-technical summary is given below.

Household behaviour is captured via a 'representative regional household', which in search for maximising its utility, collects all income that is generated in the economy and allocates it over private household and government expenditures on commodities, and savings for investment goods. Income comes from payments by firms to the regional household for the use of endowments of skilled and unskilled labour, land, capital and natural resources. The regional household also receives income from (net) taxes paid by the private household (on private consumption and income), firms (taxes on intermediate inputs and production) and the government (on its expenditures).

Firms, in search of maximising profits, produce commodities by employing the aforementioned endowments and intermediate inputs from other firms using a *constant returns to scale* production technology[1] so as to sell them to private households, the government and other producers. Domestically produced goods can either be sold on the domestic market or to other regions in the world. Similarly domestic intermediate, private household and government demand for goods can be satisfied by domestic production or by imports from other regions in the world (*Armington assumption*). These come with their own import and export taxes. Sourcing of imports happens at the border, after which - on the basis of the resulting composite import price - the optimal mix of import and domestic goods is derived.[2]

[1] This means that as firms grow, they do not become more efficient or less efficient.

[2] The Armington assumption implies that an increase in the domestic price relative to imports will lead to an increase in demand for imports relative to domestic goods. Similarly, if imports from one source country become more expensive, there will be substitution towards imports from another, cheaper, source country.

Demand for and supply of commodities and endowments meet in markets, which are perfectly competitive and clear via price adjustments. Natural resources are assumed to adjust sluggishly between sectors. The assumptions regarding the land, capital and labour markets are discussed below.

With all markets in equilibrium, firms earning zero profits and households being within their budget constraint, global savings must equal global investments. Investments are computed on a global basis, via a 'global bank' which assembles savings and disburses investments, so that all savers in the model face a common price for this savings commodity. Global savings determine global investments, i.e. the macro closure is savings driven and essentially neoclassical in nature. Since GTAP is essentially a comparative static model, investments only influence the pattern of production (via investments as a demand category) and are not installed so as to add to the productive capacity of industries over time. As the CGE model can only determine relative prices, the GDP deflator is set as the numéraire (i.e. the basic unit to represent value) of the model, against which all other prices are benchmarked. Changes in prices resulting from the model simulations thus constitute real price changes.

4.2.2 Modular extensions

For the purpose of this study, MAGNET, compared with GTAP, employs a more sophisticated production structure, a more sophisticated consumption structure, segmented labour and capital markets and improved modelling of the land market. Each of these extensions is briefly explained below in a non-technical manner. They are documented more elaborately in Woltjer et al. (2013).

The *production structure* specified in MAGNET accounts for the inherent difference in the ease of substitution between value added and intermediates (assuming constant coefficients, i.e. no substitution) and land and non-land factors of production (little substitution between land and non-land factors, and relatively more substitution between non-land factors). Standard GTAP does not allow for the latter.

The *consumption structure* specified in MAGNET allows for a better depiction of changes in diets observed over time (towards meats, dairy, fish, and away from staple foods). This is achieved by updating the income elasticities in MAGNET as a decreasing function of real GDP per capita as economies grow over time. This is an improvement over the GTAP model where constant income elasticities lead to unrealistically high consumption of food items in fast growing economies.

The *segmented factor markets specification* in MAGNET divides the market for capital, skilled and unskilled labour into an agricultural and non-agricultural market. Within each of these markets there is perfect movement, but it is more difficult to move from one to another. This results in, for example, differences in wages levels for unskilled labour in agriculture compared with non-agriculture (i.e. industry and services sectors), which is observed in reality. This forms an improvement over standard GTAP where capital and labour are perfectly mobile across sectors, which results in one wage and rental rate in the economy of a country.

The *land market specification* in MAGNET incorporates the following improvement. Land supply is endogenous, whereby overall land supplied to (and used in) agriculture positively depends on a land price (the average of all land rental rates). The general idea underlying the land supply curve specification is that the most productive land is first taken into production. However, the potential for bringing additional land into agriculture is limited. The shape of the land supply function is governed by an asymptote, the maximum amount of land that is potentially available for agriculture, and a price elasticity of total land supply (and use). Closer to the asymptote the land price will increase by more as land use increases as it becomes relatively scarce. In GTAP land supplied to (and used in) agriculture is fixed, which is not conform to reality.

4.3 Scenarios

Considering that food waste in demand (retail and households) is a dominating issue with respect to food losses and/or waste in the EU and considering the impacts that we expect from economic theory, we have developed a series of scenarios by which we can analyse the impacts of reducing food waste and aim to compare it to a healthy diet scenario.

4.3.1 Reducing Food Waste (FW) scenarios

We adopt a series of Food Waste (FW) scenarios, where food waste is reduced for household and retail demand of nine final food commodities (Table 4.2). We also model a reduction in food waste by households and retail combined.

Given that reliable and consistent data on the extent by which food waste may be reduced are lacking, we propose to incorporate waste reduction percentages of 50%, 40% and 30% for both direct household demand and demand in retail; 50% reflecting the, perhaps ambitious, target aimed for by the EU

member states, 40% representing, perhaps, a more realistic target and 30% reflecting, perhaps, a modest target. We assume that these food waste reductions will be realised over the period 2012-2020, the period of interest for the EU member states. This results in a total of eight household waste reduction scenarios (where household waste reductions in processed rice - semi- or wholly milled rice - and other food have been combined), one retail waste reduction scenario and an overall scenario, which combines all waste reductions by households and in retail. Each of these are implemented using the three levels of ambition, resulting in a total of thirty scenarios focusing purely on reducing food waste in household and retail demand and keeping other things constant. Table 4.2 summarises the FW scenarios that have been incorporated for households. Table 4.3 summarises the FW scenario that has been incorporated in retail. In both tables, the first column contains the starting values, derived from FAO (2011, table for Europe). The subsequent three columns contains the modest, realistic and ambitious targets for 2020 translated into the associated waste percentages. The final column includes the scenario names, consisting of FW (Food waste), followed by the MAGNET sectors to which the shocks are applied in each scenario, and including a scenario which combines all (household consumption of food commodities and retail). Each of these names will contain a variant letter (_M, _R, or _A) depending on the variant carried out.

Table 4.2	Food waste scenarios: waste shares in household consumption (%) a)				
	Starting value	Target (by 2020) / Scenario variant			Scenario name
MAGNET sector	Base (2012)	Modest 30% (M)	Realistic 40% (R)	Ambitious 50% (A)	...._M / ...._R / ...._A
Vegetables and fruits	19.0	13.3	11.4	9.5	FW_v_f, FW_all
Fishing	11.0	7.7	6.6	5.5	FW_fsh, FW_all
Red meat	11.0	7.7	6.6	5.5	FW_rmt, FW_all
White meat	11.0	7.7	6.6	5.5	FW_wmt FW_all
Vegetable oils	4.0	2.8	2.4	2.0	FW_vol, FW_all
Dairy products	7.0	4.9	4.2	3.5	FW_mil, FW_all
Processed rice	25.0	17.5	15.0	12.5	FW_pcr_FBT, FW_all
Sugar	17.0	11.9	10.2	8.5	FW_sgr, FW_all
Other food, beverage and tobacco	25.0	17.5	15.0	12.5	FW_pcr_FBT, FW_all

a) FAO waste percentages in household demand for final food commodities have been allocated to MAGNET sectors in the base year according to commodities that are present in both that they had most in common, resulting in processed rice and other food sharing the same waste percentage. Waste percentages in fish and meats reported by FAO are identical. Sugar is assumed to inherit the waste percentage of roots and tubers. Target reductions (by 2020): Modest = 30%, Realistic = 40%, Ambitious = 50% (= the EC target as incorporated in the Roadmap towards a Resource Efficient Europe).
Source: FAO (2011) and own calculations.

Table 4.3	Food waste scenarios: waste shares assumed for retail (%) a)				
	Starting value	Target (by 2020) / Scenario variant			Scenario name
MAGNET sector	Base (2012)	Modest (M)	Realistic (R)	Ambitious (A)	...._M / ...._R / ...._A
Vegetables and fruits	10.0	7.0	6.0	5.0	FW_ret, FW_all
Fishing	9.0	6.3	5.4	4.5	FW_ret, FW_all
Red meat	4.0	2.8	2.4	2.0	FW_ret, FW_all
White meat	4.0	2.8	2.4	2.0	FW_ret, FW_all
Vegetable oils	1.0	0.7	0.6	0.5	FW_ret, FW_all
Dairy products	0.5	0.4	0.3	0.3	FW_ret, FW_all
Processed rice	2.0	1.4	1.2	1.0	FW_ret, FW_all
Sugar	7.0	4.9	4.2	3.5	FW_ret, FW_all
Other food, beverage and tobacco	2.0	1.4	1.2	1.0	FW_ret, FW_all

a) FAO waste percentages in retail's demand for final food commodities have been allocated to MAGNET sectors in the base year according to commodities that are present in both that they had most in common, resulting in processed rice and other food sharing the same waste percentage. Sugar is assumed to inherit the waste percentage of roots and tubers. Target reductions (by 2020): Modest = 30%, Realistic = 40%, Ambitious = 50% (= the EC target as incorporated in the Roadmap towards a Resource Efficient Europe).
Source: FAO (2011) and own calculations.

The shocks for households are incorporated in MAGNET via a taste shifter, which assumes that households who reduce their food waste need to consume less food to maintain the same utility level as before, which results in lower consumption by households of the respective food commodity items (see Table 4.2). In the absence of knowledge on how the saved expenditures will be used, it is assumed that demand for all (food and non-food) commodities increases equi-proportionally and to the extent that households remain on their budget constraint.[1]

The shocks for retail are incorporated in MAGNET via the (intermediate) demand of the retail sector for the respective commodities. They are incorporated into one scenario as the commodities often come together.

We incorporate the shocks up to 2020, the year by which the targets should ideally be achieved. Knowledge on what happens afterwards is unknown. The

[1] Of course when the preference shift is implemented it will trigger a general equilibrium response to the changing demand pattern, which is likely to change households' income and so expenditures. Note also that since the saved expenditures from food waste benefits household consumption of all food commodities, including the commodities for which taste originally declines, the decrease in demand for this particular commodity is dampened somewhat. For all other commodities household demand will increase, given household income.

results however can easily be extrapolated into the future, using the outcomes for the period 2012-2020, which would show longer-term impacts if consumers were to sustain reducing waste until after 2020.

Scenarios on reducing losses in agricultural supply and processing sectors can also be carried out using FAO data, but for now have not been included given the focus on reducing food waste in household consumption and retail in the EU. This could be done in follow-up research.

4.3.2 Healthy diet (HD) scenario

A second scenario incorporates the healthy diet guidelines of the WHO (scenario taken from the study by Westhoek et al., 2011). This allows us to compare the outcomes of the overall household and retail food waste reduction scenario, which could result in unintended secondary effects on land use, health and the environment, with the outcomes of a change in diet that tries to prevent those effects. Table 4.4 summarises the assumptions of the HD scenario. Given the focus on resource efficiency, the scenario focuses on a change towards a healthier diet based on reducing the share of animal based products, i.e. red meat, white meat and dairy products. The shocks in Westhoek et al. (2011) were computed by PBL, on the basis of WHO guidelines on calories, proteins, fats, etc. Since the original shocks were based on per capita consumption levels for the year 2000, the shocks had to be adjusted for the increase in per capita consumption of red meat, white meat and dairy products since then, resulting in slightly more negative shocks to conform to the healthy diet guidelines. The shocks have been imposed on per capita household consumption of the respective commodities in the EU, allowing the households to redistribute expenditures towards other commodities in line with preferences and as far as the household budget permits.

Table 4.4 **Healthy Diet Scenario: per capita EU household consumption shifts (% change) a)**

MAGNET sector	**Shocks (2012-2020)**
Red meat	-56
White meat	-32
Dairy products	-13

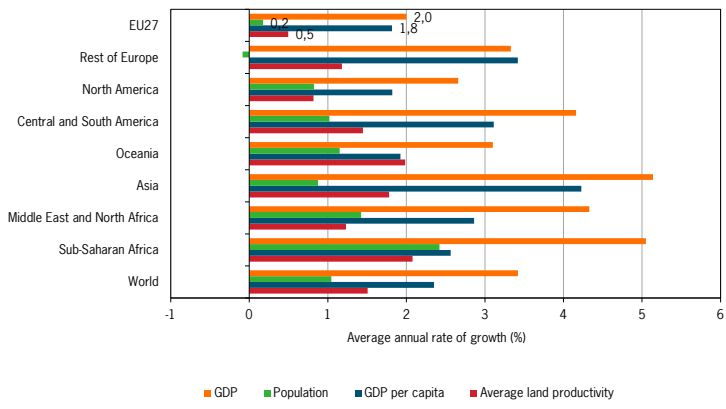
a) Retail, wholesale, hotels and restaurants' use of these commodities has been shocked downward to the same extent so as to include healthier diet choices in eating out (and given that a healthy diet guideline for this broad food consuming sector does not exist as such).
Source: based on Westhoek et al. (2011).

4.3.3 Business as Usual (BaU) scenario

Aforementioned scenarios will be implemented in addition to a baseline, 'Business as Usual', BaU, scenario. The BaU scenario reflects a future in which major socio-economic drivers follow current trends and assumes that there are no major policy changes. The BaU scenario projects the economy forward, from 2007 onwards, using USDA-ERS (2012) data on GDP and population. It assumes a return toward long-run steady growth after the global recession and financial crisis, and decreasing population growth across the world. Labour supply follows the growth path of population, whereas capital follows that of GDP ensuring that the capital-output ratio is roughly constant over time, as we generally observe. Yields will keep on increasing at the same pace as in the past and are derived from the IMAGE (Integrated Model to Assess the Global Environment) model and based upon FAO projections (Bruinsma, 2003; MNP, 2006). Technological progress is assumed to be labour saving and faster in manufacturing and then agriculture relative to services. We assume that in the BaU (from 2007 to 2012, and onwards) wasteful behaviour by households and retail in the EU (or elsewhere) does not change.

Figure 4.1 displays the main drivers in the BaU for the EU, the other regions in the model and the world in total.

Figure 4.1 **Baseline (BaU) GDP, population and yield assumptions for 2012-2020**



Source: GDP and population projections: USDA-ERS (2012), Yield projections: Bruinsma (2003); MNP (2006).

The results of the scenarios will be reported in difference from the BaU since we are interested in isolating the impacts of the FW and HD scenarios respectively. We report the results for the near future, the target year of interest for EU member states (2020), but with a possibility to look beyond (e.g. up to 2030), by extrapolating the results further.

Example
If the outcome of an indicator in 2020 is USD10,000 under the BaU and USD11,000 under an alternative scenario, the result reported is a 10% increase relative to the BaU outcome in 2020 (i.e. percentage difference) or a USD1,000 increase in absolute value (note that this in constant 2007 US dollars, as the base year data on which the model is calibrated are from 2007).

With the exception of stock variables such as land use, the results are annual results assuming waste behaviour does not change.

4.4 Indicators used to present the results

Within the possibilities of the MAGNET model and using existing knowledge on what we may expect to happen in the literature and from economic theory, we propose to look at a set of indicators with direct (EU) policy relevance. We have grouped them into demand side indicators, supply side indicators, resource use indicators, job market indicators and international trade indicators.

4.4.1 Demand side indicators

The demand side indicators we present include the absolute change in per capita income (GDP), the percentage difference in household consumption and the percentage difference in household consumption prices by type of commodity (food and non-food as specified in Table 4.1) and a food aggregate (saying something about food security as a whole). The results are presented for 2020, for the EU and, with respect to the food aggregate, for the rest of the world.

Using these indicators we may verify whether (food) consumers in the EU are better off in the form of higher consumption and lower prices (i.e. if food security in the EU improves). Using the *share of animal-based consumption in household diets*, we may also be able to say something about diet quality or composition, i.e. do diets in the EU become less healthy following reductions in food waste, taking into account possible secondary effects that may arise? Finally, we can also verify if food security improves elsewhere in the world, nota-

bly in SSA. Since MAGNET cannot distinguish different types of households, these indicators are presented for the 'average' household.

4.4.2 Supply side indicators

The supply side indicators we present include the *percentage difference in production* and the *percentage difference in production prices* for all sectors. The results are presented for 2020, for the EU.

Using these indicators we may verify whether agri-food producers in the EU are worse off (via lower producer prices and production) and other (non agri-food) producers are better off and what the main mechanisms are.

4.4.3 Resource use indicators

The resource use indicators focus on land use in agriculture. Specifically, we show the *change in total land use in agriculture and by land using sector* for 2020, for the EU.

Using these indicators we can assert if land is freed up following reductions in food waste and/or whether land use increases elsewhere due to secondary effects.

4.4.4 Job market indicators

The job market indicators focus on the *percentage difference in real wages* and *employment in agricultural and non-agricultural* (industry and services) sectors respectively. The results are presented for 2020, for the EU. Since unemployment is absent in the model, changes only tell us something about relative performance of agricultural versus non-agricultural labour markets.

4.4.5 International trade indicators

The international trade indicators focus on what happens to *trade of the EU block* with the rest of the world, including the percentage difference in exports and the percentage difference in imports. Results are reported for 2020, and for the commodities under consideration.

4.4.6 GDP indicator

A GDP indicator is used to describe what happens to the size of the economy (in million USD), for the EU and the rest of the world, in 2020. Note that GDP is not

a good indicator of welfare as it does not capture what happens to the demand side (consumer welfare).

4.5 Delimitations

It is important to bear in mind that the scenarios carried out in this study are not equal to forecasts. Instead, the scenarios are storylines with a coherent set of assumptions that together describe potential but plausible futures, in this case what may happen if the EU modestly, realistically or ambitiously reduces food waste or moves towards a more healthy diet, and reveals the underlying mechanisms of the patterns that we may see occurring. It thereby helps policy makers, researchers and other stakeholders to envision what the future may look like and guide the formulation of policies in the area of resource efficiency. It is also important to realise that the model used is, by definition, a simplification of reality. It is of the Computable General Equilibrium type and so suitable to analyse changes over the long term. Issues such as short-term price volatility are best addressed with a different type of model. Due to its firm foundation in microeconomic optimisation behaviour it is, however, particularly strong in revealing the underlying mechanisms of why things are happening following policy changes or other shocks.

MAGNET suffers from the same drawback as GTAP in that water as a natural resource is currently not well incorporated. We thus refrain from making conclusions on water use. Furthermore, impact on biofuel use is only addressed in as far as we find that, following reductions in food waste, more land becomes available for other uses. Concerning environmental impacts, only land use changes are discussed. Biodiversity impacts and GHG emissions are best addressed using the IMAGE model (NMP, 2006). Regarding the issue of waste and reducing waste, we could not incorporate all of the elements that we know are important from the theory to derive impacts of reducing food waste. Due to lack of information we model the impacts of reducing waste in the EU by a certain percentage and abstract from modelling the causes of waste itself and the cost associated with reducing waste. The outcomes of the model thus provide boundary values as to how much reducing food waste may cost so as to be worthwhile from an economic point of view (e.g. if prices fall by 10% then the unit cost of reducing waste should not be more than this 10%). Moreover we focus on waste reductions and/or diet changes only, and assume all else remains the same (*ceteris paribus* condition).

5 MAGNET results

This chapter describes the results of the MAGNET simulations on reducing waste in food demand by households and retail, wholesale, hotels and restaurants (shortened as 'retail'), in the EU (by commodity grouping and in total, and by ambition level), a simulation on a healthier diet in the EU using the WHO healthy diet guidelines, and a discussion and comparison of the scenarios.

With respect to individual commodities being analysed in the food waste scenarios, we focus on those that matter most in terms of relative importance for the EU economy, resource efficiency, and in terms of household waste. The food products analysed in more detail are red meat products, vegetables and fruits, dairy products, white meat products, sugar, 'other food' (including cereal-based products) and retail. Not analysed in detail, but included in the overall food waste scenario, are the scenarios for fish and vegetable oils and fats.

All shocks are implemented in the period 2012-2020 and the results are reported for 2020, being the target year for halving food waste in the EU (used as the ambitious target). The results are expressed in the difference from a Business as Usual (BaU) scenario. We focus on reporting results of changes in demand, supply, resource use, job market, international trade and GDP indicators that are significantly different from zero (see Chapter 4 for a description of the model and scenario setup, and reporting of indicators). The tables and figures associated with each scenario are included in an Appendix, in the order in which the indicators are discussed. The reader is advised to print the Appendix out separately so that it can be read in parallel with the description of the results.

5.1 Reducing FW in household demand for red meat (FW_rmt)

In this scenario, food waste of red meat products by households in the EU is reduced from 11% in the base year to, respectively, 5.5% in 2020 (ambitious target, implying a 50% reduction), 6.5% in 2020 (realistic target, implying a 40% reduction), or 7.5% in 2020 (modest target, implying a 30% reduction). This implies an initial shock on per capita consumption of -5.5% (ambitious target), -4.4% (realistic target), or -3.3% (modest target), respectively. Since the original shocks on meat consumption are small, the impacts on the rest of the economy, which spread throughout the system, are generally very small too. This is true for all individual scenarios analysed.

5.1.1 Demand side indicators

Per capita income, or GDP, across the globe is hardly affected by reductions in household waste of red meat in the EU. In the EU, however, per capita income is slightly negatively affected: in the ambitious scenario per capita income in the EU falls by USD1.4 , in the realistic scenario by USD1.1 and in the modest scenario by USD0.8 compared with the per capita income that would result in 2020 in the BaU. This has to do with the loss in sales for red meat producers and related sectors, as households who waste less buy less of red meat products, and the resulting fall in prices. Per capita income in other regions slightly rises, with the exception of Central and South America, North America and Oceania that are also important red meat producers and exporters, and consequently suffer from reduced demand for red meat products in the EU.

The projected fall in *per capita consumption* of red meat products by households *in the EU* is compensated for by increases in the consumption of other commodities, notably fish, white meat and milk, but also of other commodities. Household demand for retail and services is also very slightly negatively affected. Excluding the shocks that originally embodied waste in the consumption of red meat products by households in the EU (5.5, 4.4 and 3.3% respectively), per capita consumption of red meat products by households in the EU is actually going up slightly by 0.06% in the ambitious scenario, 0.05% in the realistic scenario and 0.04% in the modest scenario.[1]

Households in the *EU* benefit from lower *market prices for food products* across the board. This has to do with a fall in the average land rental rate following from the fall in red meat demand and so reduced demand for cattle (the average land rental rate falls by 0.5% in the ambitious scenario, 0.4% in the modest scenario and 0.3% in the realistic scenario compared with the BaU result in 2020), which lowers the production costs for all agri-food sectors.

Considering *dietary change in the EU*, the reduction in demand for red meat products and increased demand for other types of food implies an improvement in human diets, to the extent that the consumption of vegetables and fruits, fish, white meat, vegetable oils, and 'other food' products (including cereal-based products) goes up. The increase in household consumption of dairy products (including also butter and cheese) and sugar represents a worsening in diet. The red meat consumption change itself contains waste within the household, and

[1] See also Chapter 3, Section 3.3.5, for an explanation using the theory. Note that ideally one should take out all the household waste that is present (i.e. the remaining percentage that is not tackled in this scenario, and also perhaps for the other commodities, but we are not sure whether this waste is avoidable and/or whether it is feasible to be reduced).

so we should take this out (see before) and then on net the consumption of red meat products slightly increases. If we were to take out the total waste in each commodity group (see Chapter 4, Table 4.2), the share of animal-based products or intake in the diet of the average EU household increases very slightly (figures too small to be reported).

In order to assess the impacts on *food security in the EU and elsewhere*, we look at how composite food consumption and prices paid by households are affected, calculating the (weighted) average of volumes of agri-food commodities consumed by and associated prices paid by households, weighted with the shares of these commodities in the household budget. We notice that food consumption by households in the EU (and for the world overall) falls due to the fall in red meat household waste. Since this represents a waste reduction, it does not signify a change in food security (and we have seen that excluding waste, food consumption of red meat in the EU actually slightly goes up). If we were to exclude red meat consumption, both within the EU and the world as a whole, food consumption goes up due to the observed fall in food prices. In the rest of the world the same pattern can be observed, despite the decrease in per capita income in meat producing countries. Using the indicators of household food consumption and prices paid by households for this food consumption, we can say that for the average household food security improves in the EU and the rest of the world.[1]

5.1.2 Supply side indicators

Following the reduction in household waste and so demand for red meat products, producers of red meat products in the *EU* see their *production volumes* fall by 4.3, 3.5 and 2.6% respectively in the ambitious, realistic and modest scenarios compared with the outcomes for 2020 in the BaU. This also leads to a contraction of the cattle sector by 2.1, 1.7 and 1.2% respectively, which in terms of its sales is highly reliant on demand from the red meat product sector. The same is true for other primary agricultural products and cereals, but the effects are much smaller (generally less than 0.1% in absolute value). The other sectors generally benefit from increased expenditures by households and resources flowing out of the red meat sector into other sectors. So here, trade-

[1] Perhaps here also we should exclude all household waste that is present in all commodities, but then also for the other regions. This goes beyond the scope of this project and we thus assume that this waste remains constant. We present the figures for the EU and the world also excluding the commodity for which waste is reduced. We implement this approach for all subsequent scenarios.

offs between producers (red meat and related sectors versus other sectors) become apparent.

Market prices for producers in the EU fall for all agri-food and related products, which as indicated before is largely caused by a decrease in land prices.

5.1.3 Resource use indicators

Land use in the EU is quite considerably affected by the reduction in demand for red meat. Specifically, land used for cattle falls by 3,342 km^2 in 2020 compared with the BaU in the ambitious scenario, by 2,673 km^2 in the realistic scenario and by 2,004 km^2 in the modest scenario. The realistic scenario result for cattle is roughly identical to the observed decrease in land use by cattle over the period 2012 to 2020 in the BaU (2,534 km^2), so it doubles the decrease in land use by cattle that we normally would expect to happen by 2020. The decrease in land use by cattle in the EU is partially compensated for by land use increases in other sectors, notably oil seeds (increases of 131 km^2, 105 km^2 and 78 km^2 in the ambitious, realistic and modest scenarios respectively), vegetables and fruits (151 km^2, 121 km^2 and 91 km^2 increases) and raw milk (from milk-producing cows) (204 km^2, 163 km^2 and 122 km^2 increases), which are all sectors that expand. These increases in land use are, however, not enough to compensate for the decrease in land use by the cattle sector; overall land use decreases by 2,745 km^2 in the ambitious scenario, 2,196 km^2 in the realistic scenario and 1,647 km^2 in the modest scenario.

5.1.4 Job market indicators

Employment in agriculture *in the EU* falls due to a contracting cattle sector, to the benefit of other sectors, including processed foods, other manufacturing and services sectors, which, apart from red meat products, expand. As a consequence, *real EU wages* in industry and services rise slightly, whereas those in agriculture fall. Hence, people working and living on the country side as farmers or farm labourers seem to be worse off, compared with people working and living in cities. This pattern merely strengthens the pattern observed under the Bau which displays over time a decline in importance of the agricultural sector. Employment impacts are, however, small (generally less than 0.1%), which is caused by the presence of segmented factor markets by which it is difficult to move from agri to non-agri sectors and vice versa and very easy to move from one sector to the other and vice versa within agri and non-agri respectively.

5.1.5 International trade indicators

EU exports of red meat products to the rest of the world rise to compensate for the fall in domestic demand, whereas *EU imports* of red meat products fall. The same pattern is observable for *cattle*. Looking at overall trade, EU exports to the rest of the world rises, whereas EU imports generally fall (figures not included in the appendix).

5.1.6 GDP indicator

Using the indicator of *Gross Domestic Product*, the EU and all other red meat producing countries, but notably Central and South America, are worse off following reductions in red meat demand due to less waste of this food product by EU households. Specifically, in the ambitious scenario GDP in the EU falls by USD698m and in Central and South America by USD11.5m. In the realistic scenarios these figures are USD559m and USD9m, respectively, and in the modest scenario USD418m and USD7.6m, respectively. Other regions are, however, better off due to an increase in EU demand for other products. Globally, however, GDP falls in line with the losses in GDP by the EU.

The performance on this indicator should be evaluated together with performance on the other indicators.

5.2 Reducing FW in household demand for vegetables and fruits (FW_v_f)

In this scenario, food waste of vegetables and fruits by households in the EU is reduced from a significant 19% in the base year to, respectively, 9.5% in 2020 (ambitious target, implying a 50% reduction), 11.4% in 2020 (realistic target, implying a 40% reduction), or 13.3% in 2020 (modest target, implying a 30% reduction). This implies an initial shock on per capita consumption of -9.5% (ambitious target), -7.6% (realistic target), or -5.7% (modest target), respectively.

5.2.1 Demand side indicators

As before, *per capita income, or GDP, across the globe* is hardly affected by reductions in household waste of vegetables and fruits in the EU. In contrast with the previous scenario, however, per capita income in the EU is positively affected: in the ambitious scenario per capita income in the EU rises by USD2.1, in the realistic scenario by USD1.7 and in the modest scenario by USD1.3 com-

pared with the per capita income that would result in 2020 in the BaU. As will become evident, this has to do with a substitution both in consumption and in production towards other sectors, which compensates for a reduction in value added and income generated in the vegetables and fruits sector. Compared with red meat products, the vegetables and fruits sector seems much less intertwined with the rest of the economy in terms of supplying or demanding crucial intermediate inputs from other sectors, so its decline implies less of a downfall elsewhere in the economy. With the exception of the Rest of Europe and Asia, per capita income in other regions decreases slightly. Looking at the base data generated by the model, the Rest of Europe and Asia are relatively large producers of vegetables and fruits, but compared with other regions produce more for the domestic market, rather than exports (or for that matter for the EU market).

The fall in *per capita consumption* of vegetables and fruits by households *in the EU* is compensated for by increases in the consumption of other commodities, notably fish, animal-based products (meats, dairy), but also of other commodities. Excluding the shocks that originally embodied waste in the consumption of vegetables and fruits by households in the EU (9.5, 7.6 and 5.7% respectively), per capita consumption of vegetables and fruits by households in the EU is actually going up slightly by 0.05% in the ambitious scenario, 0.04% in the realistic scenario and 0.03% in the modest scenario.

Households in the *EU* benefit from lower *market prices for food products* across the board. As before, this has to do with a quite drastic fall in the average land rental rate, which now follows from a fall in vegetable and fruit demand (the average land rental rate falls by 2.2% in the ambitious scenario, 1.8% in the modest scenario and 1.4% in the realistic scenario compared with the BaU result in 2020), which lowers the production costs for all agri-food sectors.

Dietary change in the EU seems to be more negative compared with the previous scenario since the reduction in demand for vegetables and fruits is substituted for by a relatively strong increased demand for red meat, white meat and dairy products, compared with other food products. The vegetable and fruit consumption itself contributed to waste within the household, and so we should take this out (in fact, excluding the waste we have seen that actual consumption of vegetables and fruits improves slightly). If we were to take out the total waste in each commodity group (see Chapter 4, Table 4.2), the share of animal-based products or intake in the diet of the average EU household actually falls very slightly (figures too small to be reported).

Considering the impacts on *food security in the EU and elsewhere*, we notice that food consumption by households in the EU (and for the world overall) falls

due to the fall in vegetable and fruit household waste. Since this represents a waste reduction, it does not signify a change in food security (and we have seen that excluding waste, food consumption of vegetables and fruits in the EU actually slightly goes up). If we were to exclude the consumption of vegetables and fruits, both within the EU and the world as a whole, food consumption goes up due to the observed fall in food prices. It is interesting to see that the magnitude of the impacts is greater than those observed in the red meat scenario. In the rest of the world the same pattern can be observed, despite the decrease in per capita income in some regions. Using the indicators of household food consumption and prices paid by households, we can say that for the average household food security improves in the EU and the rest of the world.

5.2.2 Supply side indicators

Following the reduction in household waste and so demand for vegetables and fruits, producers of vegetables and fruits in the *EU* see their *production volumes* fall by 6.6, 5.3 and 3.9% respectively in the ambitious, realistic and modest scenarios compared with the outcomes for 2020 in the BaU. With the exception of manufacturing which experiences a very minor contraction, all other sectors in the economy expand as they benefit from increased expenditures by households and resources flowing out of the vegetables and fruits sector into other sectors. So here, trade-offs between producers are much less prevalent compared with the red meat scenario.

Market prices for producers in the EU fall for all agri-food and related products, which as indicated before is largely caused by a decrease in land prices.

5.2.3 Resource use indicators

Land use in the EU is quite considerably affected by the reduction in demand for vegetables and fruits, and more so compared with a reduction in red meat demand associated with waste.

Specifically, land used for vegetables and fruits falls by 8,750 km^2 in 2020 compared with the BaU in the ambitious scenario, by 6,991 km^2 in the realistic scenario and by 5,237 km^2 in the modest scenario. The ambitious scenario result exceeds the observed decrease in land use by vegetables and fruits over the period 2012 to 2020 in the BaU (8,046 km^2), so it more than doubles the decrease in land use by vegetables and fruits that we normally would expect to happen by 2020. The decrease in land use by the vegetable and fruit sector in the EU is partially compensated for by land use increases in other sectors, no-

tably cereals (increases of 1,537 km^2, 1,227 km^2 and 917 km^2 in the ambitious, realistic and modest scenarios respectively), other agricultural commodities (807 km^2, 644 km^2 and 482 km^2 increases) and oil seeds (517 km^2, 413 km^2 and 309 km^2 increases), which are all sectors that expand. These increases in land use are, however, not enough to compensate for the decrease in land use by the vegetable and fruit sector; overall land use decreases by 5,540 km^2 in the ambitious scenario, 4,429 km^2 in the realistic scenario and 3,321 km^2 in the modest scenario.

5.2.4 Job market indicators

Employment in agriculture *in the EU* falls due to a contracting vegetable and fruit sector, to the benefit of other sectors, including processed foods and services sectors, which expand. As a consequence, *real EU wages* in industry and services rise slightly, whereas those in agriculture fall. Hence, people working and living on the country side as farmers or farm labourers seem to be worse off, compared with people working and living in cities. This pattern merely strengthens the pattern observed under the BaU, which displays over time a decline in importance of the agricultural sector. Whilst employment impacts and wage impacts are small, they are more pronounced in the agricultural sector (employment and real wages in agriculture fall by around 1% compared with the BaU result in 2020) and exceed the labour market outcomes observed in the red meat scenario about ten times.

5.2.5 International trade indicators

EU exports of *vegetables and fruits* to the rest of the world rise to compensate for the fall in domestic demand, whereas *EU imports* of vegetables and fruits fall. The same pattern is observed for EU exports and imports of other agri-food commodities, as these become more competitive compared with the rest of the world. Looking at overall trade, EU exports to the rest of the world, however, fall, whereas EU imports rise, due to the slight contraction of EU services and manufacturing sectors excl. processed foods (figures not included in the appendix).

5.2.6 GDP indicator

Using the indicator of *Gross Domestic Product*, the EU, Asia and Rest of Europe benefit following reductions in vegetable and fruit demand due to less waste by

EU households. Specifically, in the ambitious scenario GDP in the EU rises by USD1,074m, in the realistic scenario by USD859m and in the modest scenario by USD643m. In Asia the gains are in the range of USD15m to USD24m (ranging from the modest to ambitious scenario) and in Rest of Europe the gains are in the range of USD8m to USD13m (again, from modest to ambitious scenario outcomes). Other regions, that export relatively more vegetables and fruits to the EU market, lose out. Globally, however, GDP rises and the magnitudes are in line with the gains in GDP realised by the EU. This result is very different from the red meat scenario where GDP in the EU and the world was observed to fall following a reduction in red meat waste.

The performance on this indicator should be evaluated jointly with performance on the other indicators.

5.3 Reducing FW in household demand for dairy products (FW_mil)

In this scenario, food waste in dairy products (milk, butter, cheese) consumed by households in the EU is reduced from 7% in the base year to, respectively, 3.5% in 2020 (ambitious target, implying a 50% reduction), 4.2% in 2020 (realistic target, implying a 40% reduction), or 4.9% in 2020 (modest target, implying a 30% reduction). This implies an initial shock on per capita consumption of -3.5% (ambitious target), -2.8% (realistic target), or -2.1% (modest target), respectively.

5.3.1 Demand side indicators

Per capita income, or GDP, across the globe is hardly affected by reductions in household waste of dairy products in the EU. In the EU, however, per capita income is negatively affected (even if only by a small amount): in the ambitious scenario per capita income in the EU falls by USD1.7, in the realistic scenario by USD1.4 and in the modest scenario by USD1 compared with the per capita income that would result in 2020 in the BaU. This is related to the loss in sales for dairy producers and related sectors (especially raw milk), as households who waste less buy less of dairy products, and the resulting fall in prices. Per capita income in other regions slightly rises, with the exception of Central and South America (and North America in the modest scenario) that is also an important dairy producer and exporter, and consequently its dairy and related sectors suffer from reduced demand for dairy products in the EU.

The fall in *per capita consumption* of dairy products by households *in the EU* is compensated for by increases in the consumption of other commodities, notably fish, white meat and red meat, but also of other commodities. Household demand for retail and services is very slightly negatively affected. Excluding the shocks that originally embodied waste in the consumption of dairy products by households in the EU (3.5, 2.8 and 2.1% respectively), per capita consumption of dairy products by households in the EU is actually going up slightly by 0.1% in the ambitious scenario, 0.08% in the realistic scenario and 0.06% in the modest scenario.

Households in the *EU* benefit from lower *market prices for food products* across the board. This is caused by a quite drastic fall in the average land rental rate following from a fall in dairy products demand and so reduced demand for raw milk from milk producing cows (the average land rental rate falls by 1.2% in the ambitious scenario, 1% in the modest scenario and 0.7% in the realistic scenario compared with the BaU result in 2020), which lowers the production costs for all agri-food sectors.

It is difficult to conclude anything about *dietary change in the EU*, as the reduction in demand for dairy products (itself simply a reduction of waste) leads to an increased demand for red meat (not so healthy), white meat (better than red meat), fish (also better), sugar (not so good) and other food products including vegetables and fruit, vegetable oils and cereal based-products (all generally healthier options). If we were to take out the total waste in each commodity group (see Chapter 4, Table 4.2), the share of animal-based products or intake in the diet of the average EU household increases very slightly (figures too small to be reported).

Considering the impacts on *food security in the EU and elsewhere*, we see that food consumption by households in the EU (and for the world overall) falls due to the fall in household waste of dairy products. Since this represents a waste reduction, it does not signify a change in food security (and we have seen that excluding waste, food consumption of dairy in the EU actually slightly goes up). If we were to exclude dairy consumption, both within the EU and the world as a whole, food consumption goes up due to the observed fall in food prices. In the rest of the world the same pattern can be observed, despite the decrease in per capita income for some countries. Using the indicators of household food consumption and prices paid by households for this food consumption, we can conclude that for the average household food security improves in the EU and the rest of the world.

5.3.2 Supply side indicators

Following the reduction in household waste and so demand for dairy products, producers of red dairy in the *EU* see their *production volumes* fall by 2.5, 2 and 1.5% respectively in the ambitious, realistic and modest scenarios compared with the outcomes for 2020 in the BaU. This leads to, especially a contraction of the raw milk sector by 1.9, 1.5 and 1.2% respectively, which in terms of its sales is highly reliant on demand from the dairy sector. In some other sectors a similar effect can be observed (e.g. cereals, used as feed to milk producing cows), but the effects are much smaller (generally less than 0.1% in absolute value). The other sectors generally benefit from increased expenditures by households and resources flowing out of the dairy sector into other sectors. So again, trade-offs between producers become apparent.

Market prices for producers in the EU fall for all agri-food and related products, which as indicated before is largely caused by a decrease in land prices.

5.3.3 Resource use indicators

Land use in the EU is quite considerably affected by the reduction in demand dairy products. Specifically, land used in producing raw milk (by milk producing cattle) falls by 7,547 km^2 in 2020 compared with the BaU in the ambitious scenario, by 6,034 km^2 in the realistic scenario and by 4,523 km^2 in the modest scenario. The realistic scenario result for milk producing cattle is approximately half the observed decrease in land use by this same sector over the period 2012 to 2020 in the BaU (13774 km^2). The decrease in land use by milk producing cows in the EU is partially compensated for by land use increases in other sectors, notably vegetables and fruits (increases of 319 km^2, 255 km^2 and 191 km^2 in the ambitious, realistic and modest scenarios respectively), and oil seeds (300 km^2, 240 km^2 and 180 km^2 increases), which are all sectors that expand. These increases in land use are, however, not enough to compensate for the decrease in land use by the milk sector; overall land use decreases by 6,043 km^2 in the ambitious scenario, 4,831 km^2 in the realistic scenario and 3,620 km^2 in the modest scenario. These impacts exceed those observed in the red meat scenario, but not those observed in the vegetables and fruits scenario.

5.3.4 Job market indicators

Employment in agriculture *in the EU* falls due to a contracting raw milk sector, to the benefit of other sectors, notably red and white meat products, and services sectors, which, expand. As a consequence, *real EU wages* in industry and services rise slightly, whereas those in agriculture fall. Hence, people working and living on the country side as farmers or farm labourers seem to be worse off, compared with people working and living in cities. As before, this pattern merely strengthens the pattern observed under the Bau which displays over time a decline in importance of the agricultural sector. Employment impacts are, however, very small.

5.3.5 International trade indicators

EU exports of *dairy products* to the rest of the world rise to compensate for the fall in domestic demand, whereas *EU imports* of dairy products fall. The same pattern is observable for *raw milk* (figures not included in the appendix as trade in raw milk from and to the EU is relatively small). Looking at overall EU trade (exports, imports) with the rest of the world, the same pattern can be observed (figures not included in the appendix).

5.3.6 GDP indicator

Using the indicator of *Gross Domestic Product*, EU and Central and South America as are worse off following reductions in dairy demand due to less waste of this food product by EU households. Specifically, in the ambitious scenario GDP in the EU falls by USD860m and in Central and South America by USD6.7m. In the realistic scenarios these figures are USD689m and USD5.1m, respectively, and in the modest scenario USD516m and USD3.9m , respectively. Other regions are, however, better off due to an increase in EU demand for other products. Globally, however, GDP falls in line with the losses in GDP by the EU. These losses are higher than those observed in the red meat scenario.

The performance on this indicator should be evaluated in combination with performance on the other indicators.

5.4 Reducing FW in household demand for white meat (FW_wmt)

In this scenario, food waste of white meat products (chicken and pig meat) by households in the EU is reduced from 11% in the base year to, respectively, 5.5% in 2020 (ambitious target, implying a 50% reduction), 6.5% in 2020 (realistic target, implying a 40% reduction), or 7.5% in 2020 (modest target, implying a 30% reduction). This implies an initial shock on per capita consumption of -5.5% (ambitious target), -4.4% (realistic target), or -3.3% (modest target), respectively.

5.4.1 Demand side indicators

Per capita income, or GDP, across the globe is hardly affected by reductions in household waste of white meat in the EU. In the EU per capita income is slightly negatively affected: in the ambitious scenario per capita income in the EU falls by USD0.95 , in the realistic scenario by USD0.76 and in the modest scenario by USD0.57 compared with the per capita income that would result in 2020 in the BaU. This is caused by the loss in revenues for white meat producers and related sectors (live chicken and pigs, and cereals as important feed for chicken), as households who waste less buy less of white meat products, and the resulting fall in prices. Per capita income in other regions slightly rises, with the exception of Central and South America and North America that are also important white meat producers and exporters, and consequently suffer from reduced demand for white meat products in the EU.

The fall in *per capita consumption* of white meat products by households *in the EU* is compensated for by increases in the consumption of other commodities, notably fish, milk, and red meat, but also of other commodities. Excluding the shocks that originally embodied waste in the consumption of white meat products by households in the EU (5.5, 4.4 and 3.3% respectively), per capita consumption of white meat products by households in the EU actually increases slightly by 0.13% in the ambitious scenario, 0.10% in the realistic scenario and 0.08% in the modest scenario.

Households in the *EU* benefit from lower *market prices for food products* across the board. This is related to a fall in the average land rental rate following from a fall in white meat demand and so reduced demand for cereals (the average land rental rate falls by 0.23% in the ambitious scenario, 0.18% in the modest scenario and 0.14% in the realistic scenario compared with the BaU result in 2020), which lowers the production costs for all agri-food sectors.

As with the dairy product scenario, it is difficult to conclude anything about *dietary change in the EU*, as the reduction in demand for white meat (itself a reduction of waste) leads to an increased demand for red meat (not so healthy), dairy products (including milk, but also butter and cheese), fish (healthier), sugar (not so healthy) and other food products including vegetables and fruit, vegetable oils and cereal based-products (all generally healthier options). If we were to take out the total waste in each commodity group (see Chapter 4, Table 4.2), the share of animal-based products or intake in the diet of the average EU household increases very slightly (figures too small to be reported).

Considering the impacts on *food security in the EU and elsewhere*, the results show that food consumption by households in the EU (and for the world overall) falls due to the decrease in household waste of white meat products. Since this represents a waste reduction, it does not signify a change in food security (and we have seen that excluding waste, food consumption of white meat in the EU actually slightly goes up). If we were to exclude white meat consumption, both within the EU and the world as a whole, food consumption goes up due to the observed fall in food prices. In the rest of the world the same pattern appears, despite the decrease in per capita income for some countries. Using the indicators of household food consumption and prices paid by households for this food consumption, we can conclude that for the average household food security improves in the EU and the rest of the world.

5.4.2 Supply side indicators

Following the reduction in household waste and so demand for white meat products, producers of white meat products in the *EU* see their *production volumes* fall by 4.4, 3.5 and 2.7% respectively in the ambitious, realistic and modest scenarios compared with the outcomes for 2020 in the BaU. This also leads to a contraction of the live chicken and pig sector by 2.8, 2.2 and 1.7% respectively, which in terms of its sales is highly reliant on demand from the white meat product sector. The same is true for other cereals and so cattle, and to a lesser extent raw milk, depending on cereals for its feed, but the effects are much smaller (generally less than 1% in absolute value). The other sectors generally benefit from increased expenditures by households and resources flowing out of the white meat and related sectors into other sectors. So here, similar to the red meat scenario, trade-offs between producers (white meat and related sectors versus other sectors) become apparent.

Market prices for producers in the EU fall for all agri-food and related products, which as indicated before is largely caused by a decrease in land prices.

5.4.3 Resource use indicators

Land use in the EU is quite considerably affected by the reduction in demand for white meat. Notable, land used for cereals falls by 2,143 km^2 in 2020 compared with the BaU in the ambitious scenario, by 1,714 km^2 in the realistic scenario and by 1,285 km^2 in the modest scenario. This is, however, only a fraction of the observed decrease in land use by cereals over the period 2012 to 2020 in the BaU (33,073 km^2). Land use by cattle (depending on cereals for its feed) and raw milk (from milk producing cows) also falls by 1,350 km^2, 1,080 km^2 and 810 km^2 for cattle and by 103 km^2, 82 km^2 and 61 km^2 for raw milk respectively. The decrease in land use by cereal and related sectors in the EU is partially compensated for by land use increases in other sectors, notably vegetables and fruits (increases of 219 km^2, 175 km^2 and 131 km^2 in the ambitious, realistic and modest scenarios respectively), and oil seeds and other agriculture (each experience about 185 km^2, 148 km^2 and 111 km^2 increases in the ambitious, realistic and modest scenarios), which are all sectors that expand. These increases in land use are, however, not enough to compensate for the decrease in land use by cereal and related sectors; overall land use decreases by 3,005 km^2 in the ambitious scenario, 2,403 km^2 in the realistic scenario and 1,801 km^2 in the modest scenario, slightly more than the declines in land used observed in the red meat scenario.

5.4.4 Job market indicators

Employment in agriculture *in the EU* falls due to contracting live chicken and pigs, cereal, cattle and raw milk sectors, only slightly to the benefit of other sectors, including processed foods, other manufacturing and services sectors, which, apart from white meat products and 'other food' products, expand. As a consequence, *real EU wages* in industry and services rise slightly, whereas those in agriculture fall. So, again, as in all previous scenarios people working and living on the country side as farmers or farm labourers seem to be worse off, compared with people working and living in cities. As before, this pattern merely strengthens the pattern observed under the BaU which displays a decline in importance of the agricultural sector over time.

5.4.5 International trade indicators

EU exports of white meat products to the rest of the world rise to compensate for the fall in domestic demand, whereas *EU imports* of white meat products fall. The same pattern is observable for related sectors, notably *live chicken and pigs* and *cereals*. Looking at overall EU trade (exports, imports) with the rest of the world, also the same pattern can be observed (figures not included in the appendix).

5.4.6 GDP indicator

Using the indicator of *Gross Domestic Product*, the EU and all other white meat producing countries, including Central and South America and North America, are worse off following reductions in white meat demand due to less waste of this food product by EU households. Specifically, in the ambitious scenario GDP in the EU falls by USD484m , in the realistic scenario by USD388m and in the modest scenario by USD290m . In Central and South America the losses are in the range of 23 to USD14m (ranging from the ambitious to modest scenario) and in North America the losses are in the range of USD2.7-1.5m (again, from ambitious to modest scenario outcomes). Other regions are, however, better off due to an increase in EU demand for other products, notably rest of Europe (gains in the range of USD6-3.6m, ranging from the ambitious to modest scenarios). Globally, however, GDP falls and with magnitudes in line with the losses in GDP suffered by the EU. The losses are much smaller in magnitude compared with those realised in the red meat scenario.

The performance on this indicator should be evaluated together with performance on the other indicators.

5.5 Reducing FW in household demand for sugar (FW_sgr)

In this scenario, food waste in sugar consumed by households in the EU is reduced from 17% in the base year to, respectively, 8.5% in 2020 (ambitious target, implying a 50% reduction), 10.2% in 2020 (realistic target, implying a 40% reduction), or 11.9% in 2020 (modest target, implying a 30% reduction). This implies an initial shock on per capita consumption of -8.5% (ambitious target), -6.8% (realistic target), or -5.1% (modest target), respectively.

5.5.1 Demand side indicators

Per capita income, or GDP, across the globe is little affected by reductions in household waste of sugar in the EU. In the EU, however, per capita income is slightly negatively affected: in the ambitious scenario per capita income in the EU falls by USD1, in the realistic scenario by USD0.8 and in the modest scenario by USD0.6 compared with the per capita income that would result in 2020 in the BaU. This has to do with the loss in sales for sugar and the related sugar cane and beet sector, as households who waste less buy less of sugar, and the resulting fall in prices. Per capita income in other regions slightly rises, with the exception of Central and South America, Rest of Europe, Oceania and Sub-Saharan Africa that also produce and export sugar (as well as sugar cane and beet), and consequently suffer from reduced demand for sugar in the EU.

The fall in *per capita consumption* of sugar by households *in the EU* is compensated for by increases in the consumption of other commodities, notably fish, white meat, milk and red meat, but also of other commodities. Household demand for retail and services is very slightly negatively affected. Excluding the shocks that originally embodied waste in the consumption of sugar by households in the EU (8.5, 6.8 and 5.1% respectively), per capita consumption of vegetables and fruits by households in the EU is actually going up slightly by 0.03% in the ambitious scenario and realistic scenarios and 0.02% in the modest scenario.

Households in the *EU* benefit from lower *market prices for food products* across the board. This is linked to a fall in the average land rental rate following from a fall in the demand for sugar and so reduced demand for sugar cane and beet (the average land rental rate falls by 0.08% in the ambitious scenario, 0.06% in the modest scenario and 0.04% in the realistic scenario compared with the BaU result in 2020), which lowers the production costs for all agri-food sectors. The impacts are however very small as sugar cane and beet is a relatively small sector both in terms of its importance for the EU economy and in terms of land use.

As with dairy and white meat products, it is difficult to conclude anything about *dietary change in the EU*, as the reduction in demand for sugar (itself a reduction of waste) leads to an increased demand for red meat (not so healthy), white meat (better than red meat), fish (also better), dairy (including butter, and cheese) and other food products including vegetables and fruit, vegetable oils and cereal based-products (all generally healthier options). If we were to take out the total waste in each commodity group (see Chapter 4, Table 4.2), the

share of animal-based products or intake in the diet of the average EU household decreases very slightly (figures too small to be reported).

Considering the impacts on *food security in the EU and elsewhere*, we find that food consumption by households in the EU (and for the world overall) falls due to the decrease in household waste of sugar products. Since this represents a waste reduction, it does not signify a change in food security (and we have seen that excluding waste, food consumption of sugar in the EU actually slightly goes up). If we were to exclude sugar consumption, both within the EU and the world as a whole, food consumption goes up due to the observed fall in food prices. In the rest of the world the same pattern can be observed, but the impacts are too small to be discernible. Using the indicators of household food consumption and prices paid by households for this food consumption, we can say that for the average household food security improves in the EU and the rest of the world, albeit slightly.

5.5.2 Supply side indicators

Following the reduction in household waste and so demand for sugar, producers of sugar and sugar cane and sugar beet in the *EU* see their *production volumes* fall by 5, 4, 3% and 3, 2.6 and 2% respectively in the ambitious, realistic and modest scenarios compared with the outcomes for 2020 in the BaU. The other sectors generally benefit from increased expenditures by households and resources flowing out of the sugar, sugar cane and beet sectors into other sectors. So here, trade-offs between producers (sugar, cane and beet versus other sectors) occur.

Market prices for producers in the EU fall for all agri-food and related products, which as indicated before is largely caused by a decrease in land prices. The impacts are fairly small (generally less than 0.2% in magnitude).

5.5.3 Resource use indicators

Land use in the EU is affected by the reduction in demand for sugar and related sugar cane and beet, but the impacts are very small. Specifically, land used for the production of sugar cane and beet falls by 715 km^2 in 2020 compared with the BaU in the ambitious scenario, by 572 km^2 in the realistic scenario and by 429 km^2 in the modest scenario. The decrease in land use by sugar cane and beet in the EU is partially compensated for by land use increases in other sectors. These increases in land use are, however, not enough to compensate for the decrease in land use by the cattle sector; overall land use decreases by

368 km^2 in the ambitious scenario, 295 km^2 in the realistic scenario and 221 km^2 in the modest scenario. These impacts are relatively small compared with the previously discussed scenarios.

5.5.4 Job market indicators

Employment and real wage impacts in the EU are in the same direction as in previous scenarios (negative for agriculture, positive for manufacturing and services), but impacts are as with land use changes relatively small.

5.5.5 International trade indicators

EU exports of *sugar* to the rest of the world rise to compensate for the fall in domestic demand, whereas *EU imports* of sugar fall. The same pattern is observable for *sugar cane and beet*. Looking at overall trade, EU exports to the rest of the world rises, whereas EU imports generally fall (figures not included in the appendix).

5.5.6 GDP indicator

Using the indicator of *Gross Domestic Product*, the EU and other sugar and sugar cane and beet producing countries, but notably Central and South America, Sub-Saharan Africa and Rest of Europe are worse off following reductions in sugar demand due to less waste of this food product by EU households. Specifically, in the ambitious scenario GDP in the EU falls by USD491m , in the realistic scenario by USD392m and in the modest scenario by USD294m . For Central and South America these figures are USD1.7m, USD1.5m and USD0.9m and for Sub-Saharan Africa USD1.5m, USD1.2m and USD1m. Other regions benefit from increased demand for other commodities. Globally, however, GDP falls and the magnitudes are in line with the losses in GDP realised by the EU. The magnitude of the losses are in line with those of the white meat scenario.

The performance on this indicator should be evaluated together with performance on the other indicators.

5.6 Reducing FW in household demand for 'other food' (including processed rice) (FW_pcr_FBT)

In this scenario, food waste of 'other food' products (including processed rice) consumed by households in the EU is reduced from 25% in the base year to, respectively, 12.5% in 2020 (ambitious target, implying a 50% reduction), 15% in 2020 (realistic target, implying a 40% reduction), or 17.5% in 2020 (modest target, implying a 30% reduction). This implies an initial shock on per capita consumption of -12.5% (ambitious target), -10% (realistic target), or -7.5% (modest target), respectively.

The interpretation of the results of this scenario is a bit more complicated than usual as the other food, beverage and tobacco (referred to as 'other food') sector includes many, mostly food (but also some non-food) products. Since many of these are cereal-based and processed rice is the only other cereal-based food product in the model, we allocated the waste percentage for cereals in final demand of households also to the 'other food' sector. As the waste percentage is relatively high compared with other sectors, this may overstate the waste problem in this sector somewhat (but not so compared with the waste of over 40% reported at the consumer level for industrialised countries in general; FAO, 2011). Moreover, the 'other food' sector comprising all other food products in the model not distinguished separately is quite big compared with the previously discussed food commodities consumed by households (accounting for 2% of value added in the economy in the base year) but much smaller than manufacturing, services and retail (shares of 20%, 68% and 7% of value added generated in the economy in the base year respectively). It is quite strongly interlinked with most of the agri-food sectors distinguished in the model that supply a relatively large share of their output to this sector. This needs to be borne in mind when reading through and interpreting the results.

5.6.1 Demand side indicators

In the EU, *per capita income, or GDP*, is much more negatively affected by reductions in household waste of 'other food' products (including processed rice) compared with other food products: in the ambitious scenario per capita income in the EU falls by USD46, in the realistic scenario by USD37 and in the modest scenario by USD27 compared with the per capita income that would result in 2020 in the BaU. This is caused by the loss in sales for 'other food' and cereal producers and related agri-food sectors, as households who waste less buy less, and the resulting fall in prices. Per capita income in other regions

slightly rises, with the exception of Central and South America and Rest of Europe, who suffer from reduced demand for 'other food' and related agri-food commodities.

The quite drastic fall in *per capita consumption* of 'other food' and processed rice by households *in the EU* (in the range of 7 to 12%) is compensated for by increases in the consumption of other commodities, notably fish, milk, white meat, but also of other commodities. Household demand for retail, manufacturing and services is very slightly negatively affected. Excluding the shocks that originally embodied waste in the consumption of 'other food' and processed rice by households in the EU (12.5, 10 and 7.5% respectively), per capita consumption of 'other food' products and processed rice by households in the EU actually increases slightly (in the range of 0.5 to 0.7% for 'other food' and in the range of 0.6 to 0.9% for processed rice).

Households in the *EU* benefit from lower *market prices for food products* across the board. This originates from a quite drastic fall in the average land rental rate following from a decrease in demand for most primary agricultural commodities supplying to the 'other food' sector (the average land rental rate falls by 3.7% in the ambitious scenario, 3% in the modest scenario and 2.2% in the realistic scenario compared with the BaU result in 2020), which lowers the production costs for all agri-food sectors, and to a lesser extent retail, manufacturing and services.

It is difficult to conclude anything about *dietary change in the EU*, as the reduction in demand for 'other food' and processed rice (itself a reduction of waste) leads to an increased demand for red meat (not so healthy), sugar (also not so healthy), white meat (better than red meat), fish (also better), dairy (including butter and cheese), vegetables and fruits, and vegetable oils (healthy). If we were to take out the total waste in each commodity group (see Chapter 4, Table 4.2), the share of animal-based products or intake in the diet of the average EU household declines slightly (by 1.01% in the ambitious scenario, by 0.99% in the realistic scenario and by 0.85% in the modest scenario).

Considering the impacts on *food security in the EU and elsewhere*, we see that food consumption by households in the EU (and for the world overall) falls due to the decrease in household waste of 'other food' products and processed rice. Since this represents a waste reduction, it does not signify a change in food security (and we have seen that excluding waste, food consumption of other food and processed rice in the EU actually slightly goes up). If we were to exclude the consumption of these categories, both within the EU and the world as a whole, food consumption goes up due to the observed fall in food prices. Using the indicators of household food consumption and prices paid by house-

holds for this food consumption, we can say that for the average household food security improves in the EU and the rest of the world.

5.6.2 Supply side indicators

Following the reduction in household waste and so demand for 'other food' and processed rice, producers of these products in the *EU* see their *production volumes* fall by around 8, 6 and 5% respectively in the ambitious, realistic and modest scenarios compared with the outcomes for 2020 in the BaU. This also leads to a contraction of many other agri-food sectors, with the exception of milk, red meat, white meat that benefit most from the increased expenditures of savings on previously wasted commodities. Manufacturing and services also slightly expand.

Market prices for producers in the EU fall across the board and for all agri-food commodities, which as indicated is also related to a decrease in land prices.

5.6.3 Resource use indicators

Land use in the EU is quite considerably affected by the reduction in demand for 'other food', since it is so closely connected to all primary agricultural sectors. In contrast with previous scenarios, land use decreases in all sectors, notably in cereals, but also other agriculture, raw milk (from milk producing cattle) and oil seeds. Overall land use decreases by 17,033 km^2 in the ambitious scenario, 13,585 km^2 in the realistic scenario and 10,157 km^2 in the modest scenario, representing about 12.5 to 25% of the decrease in overall land use in the EU observed in the BaU (81,213 km^2).

5.6.4 Job market indicators

Employment and real wage impacts in the EU are in the same direction as in previous scenarios (negative for agriculture, positive for manufacturing and services), but impacts are much greater than in the previous scenarios.

5.6.5 International trade indicators

EU exports of *'other food'* to the rest of the world rise to compensate for the fall in domestic demand, whereas *EU imports* of 'other food' products fall. The same pattern is observable for *processed rice* (although this product is not so

important for EU trade). Looking at overall trade, EU exports to the rest of the world rises, whereas EU imports generally fall (figures not included in the appendix).

5.6.6 GDP indicator

Using the indicator of *Gross Domestic Product*, EU, Central and South America and Rest of Europe are worse off following reductions in demand for 'other food' and processed rice due to less waste of this food product by EU households. Specifically, in the ambitious scenario GDP in the EU falls by USD23bn, in the realistic scenario by USD19bn and in the modest scenario by USD14bn. For Central and South America these figures are USD47m, USD38m and USD28m respectively. Other regions are, however, better off due to increase EU demand for other products. Globally, however, GDP falls in line with the losses in GDP by the EU. These losses are the highest recorded so far, due to the relatively big importance of other food products for the EU economy.

The performance on this indicator should be evaluated together with performance on the other indicators.

5.7 Reducing FW in retail demand (FW_ret)

In this scenario, food waste in retail demand in the EU is reduced from percentages ranging from 2 to 10% (depending on the food commodity in question) in the base year to, a range of 1 to 5% in 2020 (ambitious target, implying a 50% reduction), a range of 1.2 to 6% in 2020 (realistic target, implying a 40% reduction), or a range of 1.4 to 7% in 2020 (modest target, implying a 30% reduction). This implies initial shock on retail demand for final food commodities in a range of -1 to -5% (ambitious target), -0.8 to -4% (realistic target), or -0.6 to -3% (modest target), respectively. These shocks are relatively small compared with the scenarios on reductions in household waste, as waste percentages in retail are generally lower.

The interpretation of the results of this scenario is also a bit more complicated than usual as the retail sector (including wholesale, hotels and restaurants) in GTAP also includes other trade services (accounting for approximately 7% of value added generated in the economy) and consumes many types of food. We did however only shock this sector's intermediate demand for final food commodities (the same commodities as in the scenarios of reducing waste in the household) and so we are really only looking at the issue of food waste in

retail, wholesale, hotels and restaurants. As with the 'other food' sector, it is quite strongly interlinked with most of the agri-food sectors distinguished in the model that supply a relatively large share of their output to this sector. This needs to be borne in mind when reading through the results.

5.7.1 Demand side indicators

Per capita income, or GDP, across the globe is hardly affected by reductions in retail waste of food products in the EU. In the EU, however, per capita income is positively affected: in the ambitious scenario per capita income in the EU rises by USD3.2 , in the realistic scenario by USD2.5 and in the modest scenario by USD1.9 compared with the per capita income that would result in 2020 in the BaU. As will become apparent, this has to do with the reduction in cost and increase in sales for the retail sector, which outweighs the negative impact on agri-food sectors that are selling less of their produce to retail. Per capita income in other regions slightly falls as they suffer from increased competition of EU retail and agri-food producers that, due to the drop in sales domestically, reorient towards the export market. The exceptions are Rest of Europe and Middle East and North Africa where per capita income rises (albeit only slightly). Both regions are the main suppliers of fish to the EU market (base data shares of 61 and 12% respectively) and benefit from an increased EU demand for fish (see below).

Households in the EU substitute away from agri-food commodities and manufacturing towards retail, other services and notably fish. This is because the fishing sector experiences quite a significant drop in demand for its products (of which 25% goes to retail) and as a result becomes relatively cheap compared with other food products. The same is true but to a lesser extent for the services sector (of which 7.5% goes to retail).

As a result of these changes, households in the *EU* benefit from lower *market prices for food products* across the board, although prices in manufacturing and services rises slightly. Rental rates for land are also shown to fall but by only a slight amount (around 0.1%).

It is difficult to conclude anything about *dietary change in the EU*, but we may perhaps say that eating out (in retail) as compared with eating at home is less healthy so that the observed slight increase in household demand for retail presents a worsening of EU diets. Household consumption of all food products, apart from fish, goes down. The share of animal-based products in household consumption remains the same.

Considering the impacts on *food security in the EU and elsewhere*, we look at how composite food consumption and prices paid by households are affected. We notice that food consumption by households in the EU (and for the world overall) falls due to the decrease in household consumption of most agri-food commodities apart from fish. In other regions it increases though. Using the indicators of household food consumption and prices paid by households for this food consumption, we can say that for the average household food security improves in the rest of the world.

5.7.2 Supply side indicators

Following the reduction in retail waste and so demand for agri-food commodities, producers of all agri-food commodities in the *EU* see their *production volumes* fall.

Market prices for producers in the EU fall for all agri-food and related commodities, which as indicated before is largely caused by a decrease in demand for agri-food commodities by retail and also households.

5.7.3 Resource use indicators

Land use in the EU is affected by the reduction in demand for agri-food commodities. As with the previous scenario, land use decreases in all sectors, notably in cereals, cattle and raw milk (from milk producing cattle). Overall land use decreases by 686 km^2 in the ambitious scenario, 544 km^2 in the realistic scenario and 418 km^2 in the modest scenario, comparatively small impacts.

5.7.4 Job market indicators

Employment and real wage impacts in the EU are in the same direction as in previous scenarios (negative for agriculture, positive for manufacturing and services), and impacts are, again, relatively small.

5.7.5 International trade indicators

EU exports of *agri-food products* to the rest of the world rise to compensate for the fall in domestic demand, whereas *EU imports* of agri-food products fall. Exports of retail rises as well whereas imports fall as this sector becomes more competitive compared with the rest of the world. Looking at overall EU trade

(including manufacturing and services) with the rest of the world, exports and imports fall, but impacts are very minor (figures not included in the appendix).

5.7.6 GDP indicator

As explained before, using the indicator of *Gross Domestic Product*, the EU, and to a lesser extent Rest of Europe, Asia and Middle East and North Africa are better off following waste reductions in retail. Specifically, in the ambitious scenario GDP in the EU rises by USD1,613m, in the realistic scenario by USD1,288m and in the modest scenario by USD976m. Globally, GDP rises and the magnitudes are in line with the quite considerable gains in GDP realised by the EU.

The performance on this indicator should be evaluated together with performance on the other indicators.

5.8 Reducing FW within the household and in retail (FW_all)

This scenario combines all waste shocks included in the previous scenarios concerning reducing food waste within the household and in retail in the EU, and for the three ambition levels (an ambitious reduction of 50%, a modest reduction of 40% and a realistic reduction of 30%).

5.8.1 Demand side indicators

Per capita income, or GDP, in the EU, in line with the results from the individual scenarios, is negatively affected by reductions in household and retail food waste: in the ambitious scenario per capita income in the EU falls by USD52, in the realistic scenario by USD37 and in the modest scenario by USD28 compared with the per capita income that would result in 2020 in the BaU. We know from the individual food waste in household and in retail scenarios that a big contributor of this reduction in GDP per capita is the relatively large 'other food' sector. The loss is caused by a loss in sales of agri-food sectors, as households who waste less buy less food products, as a result of which prices will also fall. Per capita income in other regions slightly rises, with the exception of Central and South America, North America and Middle East and North Africa. Central and South America, as an important agri-food producer and exporter suffers from reduced demand for all agri-food commodities from the EU. For North America, with the exception of a few commodities the same is true. For the

Middle East and North Africa, the loss in exports to the EU of vegetables and fruits seems the dominating cause of GDP losses. Note that in relative terms, compared with the per capita GDP projected in 2020 in the BaU, impacts are rather small (for the EU, the figures above represent a loss of 0.13%, 0.09% and 0.07% of GDP per capita in 2020 in the ambitious, realistic and modest scenario respectively).

Lowering household and retail waste of food products lowers *per capita household consumption* of food products *in the EU* quite a lot, due to the initial and substantial, negative shocks on per capita consumption from reducing waste. Household demand for manufacturing and services is very slightly negatively affected, which means that the fall in prices is not enough to compensate for the fall in incomes. Excluding the shocks that originally embodied waste in the consumption of food products by households in the EU, per capita consumption of food products actually goes up slightly, on average by around 1.2% in the ambitious scenario, 0.9% in the realistic scenario and 0.7% in the modest scenario. For fishing the figures are slightly higher; excluding the shocks that originally embodied waste, food consumption of fish goes up by 3.2%, 3% and 2.3% in the ambitious, realistic and modest scenarios respectively.

Households in the *EU* benefit from lower *market prices for food products* across the board. This is due to the fall in demand and translates into lower land rental rates following from a fall in demand for most primary agricultural commodities (the average land rental rate falls by 6.8% in the ambitious scenario, 5.7% in the modest scenario and 4.3% in the realistic scenario compared with the BaU result in 2020), which lowers the production costs for all agri-food sectors, and to a lesser extent retail, manufacturing and services.

It is difficult to conclude anything about *dietary change in the EU*, as the reduction in demand for food products itself implies a reduction in waste. If we were to take out the total waste in each commodity group (see Chapter 4, Table 4.2), the share of animal-based products or intake in the diet of the average EU household increases very slightly (by 1.2% in the ambitious scenario, by 0.8% in the realistic scenario and by 0.5% in the modest scenario).

Considering the impacts on *food security in the EU and elsewhere*, we see that food consumption by households in the EU (and for the world overall) falls due to the fall in household (and retail) waste. Since these represent waste reductions, they do not signify a change in food security (and we have seen that excluding waste, food consumption in the EU goes up). However, the price for agri-food commodities in the EU falls by an average of 0.7% in the ambitious scenario, 0.6% in the realistic scenario and 0.4% in the modest scenario so that food households buy in general becomes cheaper. This represents an im-

provement in food security. If we were to exclude the EU, food consumption in the world goes up (by 0.032% in the ambitious scenario and 0.027% in the modest scenario) due to the observed fall in food prices and rises in income in some regions (Oceania, Sub-Saharan Africa, Asia and Rest of Europe). Using the indicators of household food consumption and prices paid by households for this food consumption, we can say that for the average household food security improves in the rest of the world. This conclusion also holds for Sub-Saharan Africa, where food security is a concern. Here food prices fall in the range of 0.1 to 0.2% and food consumption rises in the range of 0.03 to 0.05%. The impacts of reducing food waste by households and retail on food security of this region (and also the rest of the world) is, however, small.

5.8.2 Supply side indicators

All agri-food sectors in the *EU* contract following reductions in waste in demand (by households and in retail). Specifically, agri-food *production volumes* fall by an average of 5.3% in the ambitious scenario, by 4.4% in the realistic scenario and by 3.3% in the modest scenario compared with the outcomes for 2020 in the BaU. Resources move out of agri-food sectors into manufacturing and services, which slightly expand.

Market prices for producers in the EU fall across the board, which as indicated is also related to a decrease in land prices which follows from a fall in demand for food products and so primary agricultural commodities and their demand for land. Agri-food market prices for producers decline by an average of 0.9% in the ambitious scenario, 0.7% in the realistic scenario, 0.5% in the modest scenario. In manufacturing and services, also demand inputs to some extent from agri-food sectors, prices slightly decline too.

5.8.3 Resource use indicators

Land use in the EU is hugely affected by the reduction in demand for agri-food commodities. Land use decreases in all sectors, notably in the milk sector (land use by milk-producing cows), cereals (an important feed), but also vegetables and fruits (which experiences a lot of avoidable waste). Overall land use decreases by close to 35,000 km^2 in the ambitious scenario, close to 29,000 km^2 in the realistic scenario and close to 21,600 km^2 in the modest scenario, representing 43%, 36% and 27% of the decrease in overall land use in the EU observed in the BaU (81,213 km^2).

5.8.4 Job market indicators

Employment and real wage impacts in the EU are negative for agriculture, and positive for manufacturing and services, due to the contraction of primary agricultural sectors and expansion of manufacturing and services sectors, but impacts are greater than in the previous scenarios. Specifically, employment in agriculture contracts by 3% in the ambitious scenario, 2.5% in the realistic scenario and 1.8% in the modest scenario, whereas that in other non-agri sectors expands (by 0.05, 0.04 and 0.03% respectively). Due to segmented (agri - non-agri) factor markets these impacts, which are consequently small, translate into a decrease in real wages in agriculture (by 3.1, 2.5 and 1.9% respectively) and an increase in real wages in industry and services sectors (in the range of 0.01 to 0.03%).

5.8.5 International trade indicators

EU exports of *agri-food commodities* to the rest of the world rise to compensate for the fall in domestic demand (on average by 1.9, 1.6 and 1.2% in the ambitious, realistic and modest scenarios respectively), whereas *EU imports* of agri-food commodities fall (by 7.6, 6.4 and 4.8% respectively). For total EU exports and imports the same pattern can be observed.

5.8.6 GDP indicator

Using the indicator of *Gross Domestic Product*, the EU experiences a loss of USD26.7bn in the ambitious scenario, USD18.7bn in the realistic scenario and USD14bn in the modest scenario, compared with the outcome in the BaU. Compared with the other regions that lose out (North America and Middle East and North Africa), Central and South America experience an approximate tenfold loss of USD182m, USD154m and USD116m in the ambitious, realistic and modest scenarios, respectively. These figures are, however, much smaller than the losses in the EU so that globally GDP falls in line with the losses in GDP by the EU. In relative terms, compared with the GDP projected in 2020 in the BaU, impacts are rather small (for the EU, the figures above represent a loss of 0.13%, 0.09% and 0.07% of GDP in 2020 in the ambitious, realistic and modest scenario respectively).

As before, the performance on this indicator should be evaluated together with performance on the other indicators.

5.9 A Healthy Diet scenario (HD)

In this scenario per capita household demand for red meat, white meat and dairy products falls by 56%, 32% and 15% respectively in the period 2012-2020 to conform to WHO healthy diet guidelines. Retail lowers its demand for these commodities by the same percentages so as to include healthier diet choices in eating out. Household and retail waste are assumed to remain constant.

5.9.1 Demand side indicators

Per capita income, or GDP, in the EU is negatively affected by the change in diets, but not so much as compared with the scenario in which EU food waste by households and in retail for all food products is reduced by modest to ambitious targets: specifically, per capita income in the EU falls by 19 USD compared with the BaU outcome in 2020, which is less than the 28 USD loss in the modest food waste scenario. If the food waste scenario was also targeted only to the animal-based products targeted in the healthy diet, then impacts of a healthier diet would be much greater (we know from the individual food waste scenarios that reducing food waste in red meat, white meat and dairy products would each cost the EU around USD1 in GDP per capita, so about USD3 in total). Other regions that lose out include Central and South America and North America, important meat and dairy producers and exporters. Other regions benefit from increased EU demand for non-animal-based products.

The fall in *per capita household consumption* of animal-based products *in the EU* is compensated for by an increase in consumption of other (food) products, notably fish (increase in consumption of 2.5%), but also vegetables and fruits (1.2%), vegetable oils and fats (1.3%), sugar (1.3%), processed rice (1.1%) and 'other food' (1.3%).

Households in the *EU* benefit from lower *market prices for food products* across the board. This is due to the fall in demand for animal-based products and related agri-food commodities, which translates into lower land rental rates (the average land rental rate falls by 12.7%), which lowers the production costs for all agri-food sectors, and to a lesser extent retail, manufacturing and services. Compared with a reduction in food waste within EU households and retail, these impacts, are, much larger in magnitude.

On the basis of the reduction in animal-based consumption by households, *diets in the EU* improve and become healthier, in line with the pre-imposed WHO healthy diet guidelines. Specifically, the share of animal-based products (red

meat, white meat, dairy) in EU diets declines from 32% in 2020 in the BaU to 24% in 2020 in the healthy diet scenario.

Considering the impacts on *food security in the EU and elsewhere*, we see that food consumption by households in the EU falls by 8.4% due to the fall in the consumption of animal-based products. As a result global food consumption falls by around 1.9%. However, in the EU food does become cheaper; the price for agri-food commodities in the EU falls by an average of 0.8%. This itself represents an improvement in food security. Also, as we have seen per capita consumption of food excluding animal-based products in the EU goes up. If we were to exclude the EU, food consumption in the world goes up (by 0.04%) due to the observed fall in food prices (globally by an average of 0.5%) and rises in incomes in some regions. In all regions other than the EU consumption of food goes up, but generally by less than 0.2% (and in Sub-Saharan Africa, by 0.05%). So, using the indicators of household food consumption and prices paid by households for this food consumption, we can say that for the average household food security improves in the rest of the world, even though impacts are relatively small. The impacts regarding food security slightly exceed those of reducing food waste in EU households and retail for all food products (ambitious scenario).

5.9.2 Supply side indicators

The reduction in animal-based consumption harms the meat, dairy and feed sectors in the *EU*. Specifically, *production volumes* of red meat, white meat, milk, but also cattle, chicken, raw milk and cereal sectors fall by 48%, 29%, 13%, 29%, 18%, 11% and 3%, respectively. Resources move out of these sectors into other sectors and notably vegetables and fruits (production increase of 2.9%), oil seeds (2.8%), vegetable oils (1.2%) and processed rice (1.3%) which benefit from increased household consumption.

Market prices for producers in the EU fall for the animal-based and related sectors in the range of 1% to 5%. Other agri-food sectors, and to a lesser extent retail and manufacturing and services sectors, also experience decreases in prices as a decrease in the demand for land (for milk producing cows, meat producing cows, but also cereal feed) leads to a decrease in land prices, and so lowers cost of production.

5.9.3 Resource use indicators

Land use in the EU is hugely affected by a change in consumption towards a healthy diet in the EU. Land use as expected decreases most in the cattle sector (by 46,703), followed by the raw milk sector (from milk-producing cows; 42,486 km^2 decrease) and cereals (as feed; 13,098 km^2 decrease). Since EU households, however, demand more of other non-animal based products, land use elsewhere goes up, notably by vegetables and fruits (increase of 4,871 km^2), oil seeds (4,350 km^2), other agriculture (3,026 km^2) and sugar cane and beet (182 km^2). The overall change in land use in the EU, however, is still negative and amounts to a 89,858 km^2 decrease, more than the decrease observed in the BaU (81,213 km^2). This figure exceeds the decrease in land use in the scenario whereby we reduce food waste in EU households and retail in all food products, even in the ambitious scenario (34,970 km^2 decrease in overall land use, which is less than 40% of the decrease in land use realised in the healthy diet scenario). Hence, also with respect to the indicator of resource efficiency (as captured by land use), this scenario performs better than the scenario whereby food waste in EU households and retail is reduced.

5.9.4 Job market indicators

Employment and real wage impacts in the EU are negative for agriculture, and positive for manufacturing and services, due the contraction of animal-based and related agri-food sectors and expansion of manufacturing and services sectors, and impacts are slightly larger than in the reducing food waste in EU households and retail scenario. Specifically, employment in agriculture contracts by 5%, whereas that in other non-agri sectors expands (by 0.08%). These impacts translate into approximately the same real wage changes (-5% in agriculture, +1% in non-agricultural sectors).

5.9.5 International trade indicators

EU exports of *agri-food commodities* to the rest of the world rise to compensate for the fall in domestic demand (on average by 3.3%), whereas *EU imports* of agri-food commodities fall (by 9.3% on average). For total EU exports and imports the same pattern can be observed. Impacts on agri-food trade slightly exceed those of the reducing food waste in household and retail for all scenarios.

5.9.6 GDP indicator

Using the indicator of *Gross Domestic Product*, the EU, experiences a loss, of USD9.6bn, which compares favourably to the losses realised in the reducing food waste in households and in retail scenario (USD14bn in the modest scenario). As in this scenario, Central and South America and North America also experience losses in GDP, in the former USD333m, in the latter USD59m, but these are remarkably higher than in the aforementioned food waste scenario as they are more hurt by the more drastic fall in demand for animal-based exports compared with a fall in demand for other non-animal based products. Globally, GDP falls in line with the losses in GDP by the EU.

As shown, besides a loss in GDP (per capita), this scenario performs well on food security, and very well on resource use and dietary change, but provides negative (positive) employment and real wage impacts in agriculture (industry and services).

5.10 Discussion of results

What are the main patterns resulting from the foregoing analyses? Which commodities should EU households focus on when reducing food waste viewed from the different impacts that have been observed? And how does the reduction in food waste by EU households and in retail compare to a path towards a healthy diet in the EU? This section aims to provide answers to these questions.

Before continuing, it is important to realise that reducing waste by EU households for each of the food items analysed, first and foremost, leads to household savings. From the foregoing analyses it can be calculated that these savings annually add up to USD111 per capita (in case of a 30% reduction in household waste), USD148 per capita (40% reduction) and USD185 per capita (50% reduction) measured in 2007 USD. In current euro values this amounts savings of 92, 123 and 153 euros per year respectively (using a factor of 1.12 for conversion to 2013 dollar values and a factor of 0.74 for conversion from the dollar to the euro). Relative to the average EU household budget spent on food in 2020 this represents a saving of 5, 7 or 9% respectively. Looking at the relative contributions, 8% of these savings would stem from white meat waste reductions, 7% from vegetables and fruits waste reductions, 5% from milk waste reductions and 3% from red meat waste reductions. Sugar products and fish would each account for 1%, vegetable oils and fats for 0.5%, the remainder

stemming from waste reductions in the category of other food products comprising all other (processed) food products consumed by households.

Households are assumed to spend these savings on products and services that they demand (food and non-food). Their welfare thereby increases. In the absence of knowledge on how the saved expenditures will be used it is assumed that all sectors in the economy benefit equally from the expenditures freed up from reducing food waste by households. The reallocation of household expenditures away from previously wasted foods towards other food and non-food sectors does lead to changes in the economy, with some sectors gaining and some sectors losing. These impacts, which are outcomes of the modelling exercise, are reported below.

5.10.1 Main patterns

Table 5.1 below summarise the main impacts observed in each of the scenarios. Reading through the table from left to right the following patterns emerge.

First, *food security***,** as measured by the per capita volume of food consumed by households and market prices paid by these households for food, generally is positively affected, both in EU and rest of the world (impacts are generally very small). Exceptions are, by definition, the move towards a healthy diet in the EU (implying a fall in household consumption of animal-based products which outweighs the increased consumption of other agri-food commodities) and a reduction in retail waste in the EU, whereby households substitute demand of agri-food commodities with fish, retail and other services.

The second pattern that emerges is that *dietary change impacts in the EU*, as measured by the share of animal-based products in the diet of households, are small, but negative in many of the scenarios and in the overall scenario of reducing waste by households and in retail. The limited impacts are partly inherent in the way we model consumer preferences, whereby household budget savings from reducing waste translates into equi-proportional increases in demand for all commodities, so that the impacts are spread out, but also partly due to the fact that the shocks related to reducing food waste compared with those involved in dietary change towards a healthy diet are relatively small. Section 5.10.3 compares the relative performance of the healthy diet and food waste scenarios in more detail. The negative sign (albeit small) of the impacts is due to the fact that consumers in the EU are observed to 'trade up', in that savings freed up from reducing waste are spent a little more on more 'luxurious' commodities, including animal-based products (also found by Foresight, 2011).

Table 5.1	Main outcomes of reducing food waste by households and in retail and a healthier diet in the EU a)						
SCENARIO	**Impacts on:**						
Reducing food waste in:	**Food security** (Food consumption rises? Food prices fall?)	**EU diets become healthier?** (Share of animal-based products rises or falls?)	**EU producers** (Do sectors expand or contract?)	**Resource use EU** (What happens to land use?)	**Job market EU** (Employment and real wages in agri/non-agri rise?)	**EU trade** (Exports/imports rise?)	**Value added** (GDP going up?)
household consumption of:							
Red meat	EU, Rest of World +	-	Red meat and cattle sectors - Most others +	Cattle - Other sectors + Overall -	Agriculture - Manufacturing and services +	Exports red meat, cattle + Imports red meat, cattle - Total exports + Total imports -	EU, CSA, NAM, OCE - Rest of World +
Vegetables and fruits	EU, Rest of World +	+	Vegetable and fruits sector - Most others +	Vegetable and fruits - Other sectors + Overall -	Agriculture - Manufacturing and services +	Exports vegetables and fruits + Imports vegetables and fruits - Total exports - Total imports +	EU, ROE, ASIA + Rest of world -
Dairy	EU, Rest of World +	-	Dairy, raw milk and cereal sectors - Most others +	Raw milk - Other sectors + Overall -	Agriculture - Manufacturing and services +	Exports dairy + Imports dairy - Total exports + Total imports -	EU, CSA - Rest of World +
White meat	EU, Rest of World +	+	White meat, chicken and pig, cereals, cattle and raw milk sectors - Other sectors +	Cereals, cattle, raw milk - Other sectors + Overall -	Agriculture - Manufacturing and services +	Exports white meat, live chicken, pigs and cereals + Imports white meat, live chicken, pigs	EU, CSA, NAM - Rest of World +

						and cereals - Total exports + Total imports -	
Sugar	EU, Rest of World +	+	Sugar and sugar cane and beet sector - Other sectors +	Sugar cane and beet - Other sectors + Overall -	Agriculture - Manufacturing and services +	Exports sugar, cane and beet + Imports sugar, cane and beet - Total exports + Total imports -	EU, CSA, SSA, ROE, OCE - Rest of World +
'Other food' (including processed rice)	EU, Rest of World +	+	Agri-food sectors - except red meat, white meat, milk manufacturing and services +	All sectors -	Agriculture - Manufacturing and services +	Exports 'other food' + Imports 'other food' - Total exports + Total imports -	EU, CSA, ROE - Rest of World +
retail	EU - (based only on food consumption), Rest of World +	- (based on eating out)	Agri-food sectors - Other sectors generally +	All sectors -	Agriculture - Manufacturing and services +	Exports agri-food + Imports agri-food - Total exports + Total imports -	EU, ROE, MENA + Rest of World -
Reducing food waste in households and in retail	EU, Rest of World +	+	Agri-food sectors - Other sectors generally +	All sectors -	Agriculture - Manufacturing and services +	Exports agri-food + Imports agri-food - Total exports + Total imports -	EU, CSA, NAM, MENA - Rest of World +
Healthy diet	EU - (based only on food consumption, Rest of World +	+	Meat, dairy and feed sectors - Other sectors +	Cattle, raw milk, cereals - Other sectors + Overall -	Agriculture - Manufacturing and services +	Exports agri-food + Imports agri-food - Total exports + Total imports -	EU, CSA, NAM - Rest of World +

a) - = negative impact, + = positive impact. The signs do not say anything about the size of the impacts.
Source: MAGNET simulations.

The third pattern that becomes visible is that *trade-offs arise between producers in the EU*, with animal-based product sectors being relatively strongly interlinked with related live animal and feed sectors, so that if the former are negatively impacted, the latter will also be. A similar effect occurs between sugar products and sugar cane and beet. The 'other food' sector and also the retail sector, are generally more interlinked with all other sectors and greater in size which explains why household waste reductions here, especially in the 'other food' sector, have a greater impact.

In addition, *land use in the EU* generally changes in line with sectoral developments, with some substitution away from contracting sectors towards expanding sectors (i.e. due to a fall in land prices from lower demand for agri-food commodities due to less wastage, land demand in other land-using agricultural sectors is observed to increase). However, overall land use always declines and so in all scenarios the EU saves more on land use.

The fifth finding is that *employment patterns in the EU* in all scenarios are the same and merely strengthens the ongoing process of a declining importance of the agricultural sector and increased importance of manufacturing and services in the economy, with accompanying employment and real wage decreases in agriculture, and employment and real wage increases in manufacturing and services. This suggests that additional farm support policies may be necessary to support the agricultural sector during this transition.

Moreover, *EU trade patterns* generally try to compensate for the fall in the domestic demand for food product(s) due to lower wastage via an increase in exports and a decrease in imports. The same pattern generally seems to hold for overall EU exports and imports.

With respect to the value added generated in the economy, or *GDP*, it would seem that a decrease in EU household waste of vegetable and fruits and a decrease in retail waste boosts the EU economy due to 1) increased expenditures elsewhere that generate more value added and 2) reduced costs and improved sales in retail, respectively. Otherwise, GDP in the EU falls due to contraction of sectors producing commodities for which household waste is reduced. In the healthy diet scenario, GDP in the EU falls as well, as sectors producing animal-based products contract. In these scenarios, often the GDP of Central and South America and North America also declines due to the fall in exports of animal-based produce.[1] In relative terms, GDP impacts are very small.

[1] The finding that adopting healthy diet recommendations in the EU harms meat exporters in Central and South America is also found by the study of Lock et al. (2010) which focuses on the UK and Brazil.

All in all, it becomes clear that *trade-offs come into being, not only between producers in the EU, but also between producers and consumers in the EU, across different policy objectives* (e.g. dietary change and GDP vs. consumer welfare, food security and land use) and *across countries* (notably in terms of GDP).

Food security seems to improve generally everywhere in all scenarios due to the fall in food prices, although impacts are very small. Food consumption and prices paid, however, are for the average household (GTAP and MAGNET currently incorporate a so-called 'representative household' in each country/region of the world which represents the behaviour of all households) and so this may conceal differences at the local level. We know for example that incomes matter and that rural-urban employment and (real) wage differences arise so that even if we observe that food security in general goes up, this may only be true for urban households, with rural areas being worse off. This is discussed in more detail in the next sections.

How the reductions in waste by households and in retail in the EU compare to reductions in losses on the supply side (specifically the stages of agricultural production, post-harvest handling and storage, and processing and packaging) is an area for future research. However, the EU agricultural sector is relatively small compared with other sectors of the economy, and we may assume that in the EU agri-food production processes are relatively efficient already, so that costs of additional measures to reduce losses in supply may outweigh savings. We also abstract from the issue of costs involved in reducing household and retail waste (direct cost to households may be small but indirect cost in terms of time and effort may be much higher). For retail, assuming that avoiding waste is already part of their business model, this may be a different story.

5.10.2 Relative importance of individual commodities in reducing food waste considering their impacts

We look at the relative importance of individual commodities in reducing household food waste and of reducing waste in retail in the EU by considering each of their contribution to overall GDP in the EU and resource use, taking the realistic scenario as point of departure. We also consider the impacts on food security in Sub-Saharan Africa, a region of attention when it comes to food security.

Table 5.2 shows that, *if our only concern is to increase the value added generated in the EU economy, we should focus on reducing household waste of vegetables and fruits and retail waste.* Reducing retail waste, reduces costs and increases sales of the retail sector, whereas reducing household waste of vege-

tables and fruits leads to a substitution in consumption and production towards other commodities generating a higher value added. Reducing retail waste would make up for 6% of the GDP losses that will come from realistically reducing household waste, whereas reducing household waste of vegetables and fruits would make up for 4% of GDP losses in the EU. With respect to other food products, in order to minimise GDP losses it is best to focus on vegetable oils and fats and fish, which are not so important for the EU economy compared with other sectors. Reducing household waste in animal-based sectors will hurt the economy most in terms of value added generated (and so employment and incomes). As the demand for animal-based products falls due to household waste reductions, this has a negative impact on sales and prices of animal-based, but also related live animal and feed sectors. It is important to note that this does not say anything about welfare impacts; we have seen for example that consumers in the EU are generally better off in terms of lower food prices and increased consumption of food, and also of other products; their welfare increases from reducing waste. Moreover, in relative terms GDP impacts are very small.

Table 5.2	**Contributions to gains or losses in GDP of reducing food waste in the EU a)**
Reductions in food waste that lead to a gain in EU GDP of:	**USD2,147m**
Relative contributions:	
Household waste of vegetables and fruits	40%
Retail waste	60%
Reductions in household food waste that lead to a loss in EU GDP of:	**USD2,0823m**
Relative contributions:	
Vegetable oils and fats	0.2%
Fishing	0.4%
White meat	1.9%
Sugar	1.9%
Red meat	2.7%
Dairy products	3.3%
'Other food' (including processed rice)	89.7%

a) Using outcomes of the realistic scenario. GDP is measured in constant 2007 USD. GDP in the EU in 2020 is estimated at USD 20 trillion.
Source: MAGNET simulations.

Table 5.3 shows us that, *if our only concern is to reduce land use in the EU (i.e. promote a more efficient land use in the EU), then* - excluding the relatively large 'other food' sector which comprises many food products - *we should focus on dairy due to its strong linkages with other animal and feed sectors, vegetables and fruits, where waste is big, and red and white meat sectors, also with strong linkages to live animal and feed sectors.* Specifically dairy contributes to 17% of the savings in land use, followed by vegetables and fruits (15%), both around twice as much as land use reductions from reducing household waste in white meat (8%) and red meat (8%). Overall land use savings, 28940 km^2, approximate the total land area of Belgium. This freed up land could, for example, be used for food production for exports to other countries in the world, or biofuel production to satisfy EU energy needs.

Table 5.3	**Contributions to reductions in land use of reducing food waste in the EU a)**
Total reduction in EU land use from reduced food waste by households and in retail in the EU:	**-28,940 km^2**
Relative contributions:	
'Other food' (including processed rice)	48%
Dairy products	17%
Vegetables and fruits	15%
White meat	8%
Red meat	8%
Retail	2%
Vegetable oils and fats	1%
Sugar	1%

a) Using outcomes of the realistic scenario and excluding fish as if household food waste of fish is reduced, land use in the EU actually increases slightly, by 149 km^2. Total agricultural land use in the EU in 2020 is estimated at 1.8m km^2 in the BaU.
Source: MAGNET simulations.

As noted in the previous section, the market price for food paid by households in Sub-Saharan Africa goes down and per capita food consumption of households in Sub-Saharan Africa goes up in all scenarios. Table 5.4 shows, that *if food security in Sub-Saharan Africa is our only concern, we should* - excluding the relatively large 'other food' sector - *focus on EU household waste reductions in vegetables and fruits,* contributing 22% of the improved per capita food consumption of households in Sub-Saharan Africa, almost four times as much as the contribution of EU household waste reductions of white meat (6%),

fish and dairy (each 5%). More detailed analyses of the results reveal that due to the relatively big EU household waste reductions of vegetables and fruits and the subsequent decline in prices for vegetables and fruits world-wide, households in Sub-Saharan Africa benefit from increased consumption from domestic vegetables and fruits and imported vegetables and fruits (according to the base data, households spend around 10% of their consumption budget on vegetables and fruits). Again, in relative terms food security impacts are very small.

Table 5.4	**Contributions to food security in Sub-Saharan Africa of reducing food waste in the EU a)**			
Indicator:	**Change in per capita food consumption of households**		**Change in the market price for food paid by households**	
Unit of measurement:	**Percentage difference from BaU in 2020**	**Relative contribution**	**Percentage difference from BaU in 2020**	**Relative contribution**
Reducing food waste by households in:				
'Other food', processed rice	0.023	56%	-0.096	49%
Vegetables and fruits	0.009	22%	-0.059	30%
White meat	0.003	6%	-0.011	6%
Fish	0.002	5%	-0.008	4%
Dairy	0.002	5%	-0.009	4%
Red meat	0.001	3%	-0.007	3%
Sugar	0.001	2%	-0.004	2%
Vegetable oils and fats	0.000	1%	-0.003	2%
Reducing waste in retail	0.000	0%	-0.001	0%
Reducing waste by households and in retail	0.040	100%	-0.196	100%

a) Using outcomes of the realistic scenario.
Source: MAGNET simulations.

We know that per capita income (GDP) in Sub-Saharan Africa goes down in the scenarios whereby household waste in vegetables and fruits, in sugar and retail waste is tackled, but the average food price decrease seems to compen-

sate for that. These outcomes may still conceal differences in impacts at a sub-national level. We did not report on differential labour market impacts in Sub-Saharan Africa, but the results show that in all household and retail food waste reduction scenarios and in the healthy diet scenario, employment in the agricultural sector contracts, and real wages in agriculture decline, to the benefit of manufacturing and services sectors in these countries. It may thus well be that the observed improvement in food security is only enjoyed by urban households and not by rural households. This is an area of further research (as it requires a model that is able to distinguish different types of households).[1]

5.10.3 A comparison of food waste and healthy diet scenarios

In this section we consider the relative importance of reducing EU household waste in all sectors and retail waste combined (realistic scenario) versus that of pursuing a healthy diet by 2020 in the EU. As before we focus on the indicators of GDP, resource use and food security in Sub-Saharan Africa. Table 5.5 summarises the outcomes.

It shows that *in terms of GDP, it is less costly to encourage EU households to pursue a transition towards a healthy diet than to encourage households and retail to waste less food.* Specifically, the latter scenario yields GDP losses that are around two times as much as those realised in the healthy diet scenario. The explanation is likely to be found in that food waste is tackled in and affects all agri-food sectors, whereas a healthy diet focuses only on reductions in animal-based products (and which are substituted for by gains in consumption of non-animal based food products). Similarly*, in terms of land use, it is more efficient to focus on healthier diets than to stimulate households and retail in the EU to waste less.* Specifically, savings in land use in the latter scenario are around a third of those realised in the healthy diet scenario. This is caused by the fact that animal-based sectors are relatively more intertwined with the rest of the economy, notably with live animal and feed sectors, so that a fall in demand - which is also much greater in the animal-based sectors simply because the healthy diet shocks are relatively large compared with the food waste shocks - results in a greater negative impact on land use. Finally, *a transition in the EU towards a healthy diet is also more effective in increasing food security of the average household in Sub-Saharan Africa*, although impacts in both scenarios are small. Closer analyses of these results reveal that, the divergence in wages

[1] LEI Wageningen UR is currently working on incorporating different types of households within MAGNET, but the results of this effort are not available as yet.

and employment in agriculture and non-agriculture in Sub-Saharan Africa is more pronounced in the healthy diet scenario, so even though food security on average improves more in the healthy diet scenario this may well be true only for the urban household, with the rural household being worse off compared with the food waste scenario. This is an area for future research.

Table 5.5 Relative performance of food waste and healthy diet scenarios a)

Scenario:	Reducing food waste by households and in retail in the EU (realistic scenario)		Healthy diets in the EU	
Indicator	**Absolute difference from BaU in 2020**	**Percentage difference with BaU in 2020**	**Absolute difference from BaU in 2020**	**Percentage difference with BaU in 2020**
GDP in the EU (million USD)	-18,760	-0.09	-9,604	-0.05
Agricultural land use in the EU (km^2)	-28,940	-1.59	-89,857	-4.95
Per capita food consumption by households in SSA (volume in constant 2007 USD)	0.14	0.04	0.18	0.05
Average food price paid by households in SSA (index)	-0.00	-0.20	0.00	-0.24

a) GDP is measured in constant 2007 USD. Note that total agricultural land use in the EU in 2020 is estimated at 1.8m km^2 in the BaU. GDP in the EU in 2020 is estimated at USD20 trillion .
Source: MAGNET simulations.

The limited size of the impacts in terms of food security suggests that other EU policies, such as policies that improve market access for developing countries or improve the investment climate, may be much more important in improving food security in Sub-Saharan Africa or other developing countries compared with reducing EU waste or moving towards a healthy diet.

Moreover, considering GDP and land use impacts in the EU, the findings reported in Table 5.5 suggest that it is better to accompany waste reductions by households and retail in the EU by a - in the long term more durable and sustainable - behavioural change towards a healthy diet.

5.10.4 A comparison with other applied studies on reducing food waste

To our knowledge, the study by Westhoek et al. (2011) is the only applied study so far on the impacts of reducing food waste, discussed in the context of healthy and sustainable diets. This study's analysis of food waste reductions assumes that 15% less food production is required to meet the same level of nutrition. This shock is implemented as a 15% supply chain efficiency increase on a global scale. Our study is based on more recent and up-to-date data, using FAO data for Europe by detailed commodity grouping, and focuses on reducing waste in EU household and retail demand only, using modest, realistic and ambitious target reductions. This results in shocks on food demand that are a lot smaller, generally leading to a change in demand for food of less than 10%. Naturally, the impacts in this study may also be greater, if potential waste reductions in the remainder of the supply chain, and elsewhere in the world, are included. Nonetheless, when including waste or loss reductions, especially on the supply side costs may be involved which counteract beneficial impacts (also not modelled by Westhoek et al., 2011).

Westhoek et al. (2011) also compare their food waste scenario with a healthy diet scenario (on which our healthy diet scenario has been modelled) which has been implemented only in the EU. Given the global focus, they report outcomes generally for the world in total, not just the EU, which combined with differences in the set-up of the scenarios, renders a comparison with our study very difficult. A major drawback of this study is that impacts on GDP are not reported.

The trends that come out of the study by Westhoek et al. are, however, very similar. Specifically, they find that a 15% global supply chain efficiency improvement over the period 2000 to 2030 leads to:

- a decrease in demand for livestock products of around 4.8% and a decrease in demand for crop products by 5% (Section 8.5.2). We find that, in the realistic scenario of reducing EU household and retail waste, household demand for red meat, white meat, dairy products and vegetables and fruits in the EU falls by 3.4, 3.4, 1.6 and 6.7% respectively;
- a reduction in the total agricultural area of 2.5m ha in the EU (Table 8.4, Section 8.6). We find a decrease in total agricultural area in the EU of 2.9m ha in the EU in the realistic scenario of reducing EU household and retail waste;
- a decrease in food prices (by 8% or less depending on the type of food) and an increase in food availability, which benefits net food consumers and importers and harms net food producers and exporters. Our results display similar trends in food prices and food availability, though impacts are much small in magnitude: we find that the market price for foods consumed by

households globally falls by 0.4% in the realistic scenario of reducing EU household and retail waste.

Relatively speaking, Westhoek et al. also find that, 'of the European options, a shift towards a healthier diet and a reduction in the consumption of animal products had the largest effects.' (p190). This is in line with our analyses.

5.10.5 Lessons for the future

We analysed the impacts of reducing food waste by households and in retail in the EU, and a healthy diet scenario, with a time horizon until 2020, so on the basis of impacts over an eight year period. If this behaviour was prolonged further, the trends observed would simply continue (and can be extrapolated using the available results). It is, however, likely that once these paths towards more sustainable food consumption are set into motion that the returns will be decreasing as it will be more and more difficult to reduce waste or change diet behaviour. With respect to the latter, cultural differences across the EU will also play a role. This is an area for further research.

Given the trend towards an increasing EU and world population, with increasing demands for food, fuel and feeds (as captured in the BaU scenario), *the results imply that reducing food waste by households and in retail and adopting healthier diets in the EU have an important role to play in improving resource efficiency, with even greater impacts if other industrialised regions would also take action and adopt a more sustainable and durable consumption pattern.*

6 Conclusions

We have employed a global computable general equilibrium model, MAGNET, to project impacts of reducing food waste by households and in retail in the EU and contrast this with a scenario in which EU households adopt a healthy diet following WHO recommendations on the consumption of animal-based products. Using waste data from the FAO, we calculate impacts on the basis of modest (30% reduction), realistic (40% reduction) and ambitious (50% reduction) targets to be realised in 2020, the latter target being modelled on the milestone set by the EU in 2020. We use basic economic theory to frame and evaluate the outcomes.

The outcomes are only as good as the model and the available data. A model is by definition a simplification of reality and so cannot incorporate all real-life complexities. Also the lack of consistent international data is an important constraint in terms of modelling impacts of reducing food waste. From the perspective of the model and the data the following points should be taken into account:

- From the theory we know that if there are costs associated with reducing waste these will counteract beneficial economic impacts. Also food waste itself has underlying causes (e.g. low food prices). Given the lack of data, we have assumed costs are absent and model food waste reductions as given reductions (not explained by other factors). Future research should look into these issues. For households, behavioural change may directly involve little cost, but indirectly may cost more (e.g. time and effort involved in buying fresh food more often in smaller portions). For retail, we may assume that avoiding waste is already part of their business model, so that avoiding it by even more may be relatively costly;
- The outcomes conceal differences across EU countries but can say something about the relative importance of different commodities. Future research should look into intra-EU differences in terms of extent of food waste and impacts, in terms of differences in diets and, more generally, consumer preferences which will drive how households will spend savings on previously wasted foods;
- How the reductions in EU household and retail waste interact with and compare to reductions in losses on the supply side (specifically the stages of agricultural production, post-harvest handling and storage, and processing and packaging) is an area for future research. However, the EU agricultural sector is relatively small compared with other sectors of the economy, and we

may assume that in the EU agri-food production processes are relatively efficient already so that costs of additional measures to reduce losses in supply may outweigh savings;

- Food consumption and prices paid are for the average household (MAGNET currently incorporate a so-called 'representative household' in each country/region of the world which represents the behaviour of all its households) and so this may conceal differences at the local level. Given the fall in rural employment and wages, the observed rise in food security may only be true for urban households. LEI Wageningen UR is currently working on incorporating multiple households, which could include single person households in urban areas that are known to waste more;
- Given its global scale, MAGNET is quite aggregative by nature and cannot distinguish all individual sectors and commodities, the remainder being grouped together in a relatively big 'other food' sector, which as a result accounts for a large part of the observed impacts. The model currently also accounts for a retail sector including food service sectors which, in further work, should be separated from one another. A partial equilibrium model may incorporate more detailed sectoral impacts but cannot capture interactions between the various sectors and markets in the global economy;
- Finally, when it comes to resource efficiency, MAGNET can only address the implications for land use. Implications for water, biodiversity and GHG emissions are better addressed with other models (e.g. with a partial equilibrium model such as CAPRI, or the IMAGE model of the Netherlands Environmental Assessment Agency, PBL).

7 Literature

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Appendix 1

Tables and Figures

All Tables and Figures have been produced using the MAGNET model (see description in Chapter 4). FW stands for food waste, HD for healthy diet.

A.1 FW_rmt scenario

Table A1.1	FW_rmt: GDP per capita (2020) (2007 USD, in difference from the BaU)								
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**
FW_rmt_A	-0.003	-0.005	-0.018	0.000	0.002	-1.369	0.009	0.003	-0.092
FW_rmt_R	-0.001	-0.003	-0.014	0.000	0.001	-1.097	0.008	0.002	-0.074
FW_rmt_M	-0.001	-0.002	-0.010	0.000	0.001	-0.820	0.005	0.002	-0.055
BaU value in 2020	35,828	52,576	9,548	1,470	5,535	39,390	12,372	7,912	10,466

Table A1.2	FW_rmt: Per capita consumption by EU households (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_rmt_A	0.034	0.038	0.037	0.048	0.038	0.033	-5.439	0.066	-0.003	0.046	0.003	-0.001
FW_rmt_R	0.027	0.031	0.029	0.038	0.030	0.027	-4.351	0.053	-0.002	0.037	0.002	-0.001
FW_rmt_M	0.020	0.023	0.022	0.029	0.023	0.020	-3.263	0.039	-0.002	0.028	0.002	-0.001

Table A1.3	FW_rmt: Market prices for consumer goods in the EU (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_rmt_A	-0.089	-0.025	-0.011	-0.026	-0.012	-0.014	-0.058	-0.065	-0.002	-0.031	0.000	0.000
FW_rmt_R	-0.071	-0.020	-0.009	-0.021	-0.010	-0.011	-0.046	-0.052	-0.001	-0.025	0.000	0.000
FW_rmt_M	-0.053	-0.015	-0.007	-0.015	-0.007	-0.009	-0.035	-0.039	-0.001	-0.019	0.000	0.000

Table A1.4	FW_rmt: Food security indicators (2020) (%, in difference from the BaU) a)										
Per capita food consumption by households										**excluding red meat**	
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**	**EU27**	**WORLD**
FW_rmt_A	0.006	0.002	0.002	0.002	0.001	-0.228	0.002	0.002	-0.050	0.040	0.010
FW_rmt_R	0.005	0.001	0.001	0.001	0.001	-0.182	0.002	0.001	-0.040	0.032	0.008
FW_rmt_M	0.003	0.001	0.001	0.001	0.001	-0.136	0.001	0.001	-0.030	0.024	0.006
Market price of foods consumed by households											
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**		
FW_rmt_A	-0.015	-0.002	-0.011	-0.008	-0.003	-0.017	-0.007	-0.007	-0.013		
FW_rmt_R	-0.012	-0.001	-0.008	-0.007	-0.002	-0.014	-0.005	-0.006	-0.010		
FW_rmt_M	-0.009	-0.001	-0.006	-0.005	-0.002	-0.010	-0.004	-0.004	-0.008		
a) Foods consumed by households include all agri-food commodities consumed by households.											

Table A1.5	FW_rmt: Sectoral production in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_rmt_A	0.013	0.072	0.076	-0.035	0.011	0.042	-2.064	0.032	-0.014	0.003	0.007	0.034	0.016	-0.024	0.034	-4.313	0.001	-0.003	0.048
FW_rmt_R	0.011	0.057	0.061	-0.028	0.009	0.033	-1.651	0.025	-0.011	0.002	0.006	0.027	0.013	-0.019	0.027	-3.450	0.001	-0.002	0.038
FW_rmt_M	0.008	0.043	0.045	-0.021	0.007	0.025	-1.238	0.019	-0.009	0.002	0.004	0.020	0.010	-0.014	0.021	-2.587	0.001	-0.002	0.029

Table A1.6	FW_rmt: Market prices for producers in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_rmt_A	-0.091	-0.092	-0.112	-0.108	-0.112	-0.093	-0.137	-0.030	-0.012	0.000	0.000	-0.026	-0.014	-0.097	-0.021	-0.057	-0.071	-0.002	-0.034
FW_rmt_R	-0.073	-0.074	-0.090	-0.086	-0.090	-0.074	-0.109	-0.024	-0.010	0.000	0.000	-0.021	-0.011	-0.078	-0.017	-0.046	-0.057	-0.001	-0.027
FW_rmt_M	-0.054	-0.055	-0.067	-0.065	-0.068	-0.056	-0.082	-0.018	-0.007	0.000	0.000	-0.016	-0.009	-0.058	-0.013	-0.034	-0.043	-0.001	-0.020

Table A1.7	FW_rmt: Change in land demand per sector in the EU (2020) (km^2) a)								
Difference:	**Scenario**	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**ctl**	**CER**	**TOTAL**
From 2012	BaU	-2,605	-9,212	-8,046	-11,969	-13,774	-2,534	-33,073	-81,213
From 2020 (BaU)	FW_rmt_A	12	131	151	12	204	-3,342	87	-2,745
From 2020 (BaU)	FW_rmt_R	9	105	121	10	163	-2,673	69	-2,196
From 2020 (BaU)	FW_rmt_M	7	78	91	7	122	-2,004	52	-1,647

a) This table reveals incremental changes in land use. The second row reports the difference in 2020 from 2012 in the reference BaU scenario. The third, fourth and fifth row report the results occurring in the red meat scenarios (ambitious, modest and realistic versions) in 2020 in difference from the BaU scenario result in 2020.

Table A1.8	FW_rmt: Real wage and employment impacts in the EU (2020) (%, in difference from the BaU) a)			
Scenario	**Employment**		**Real wage**	
	Agriculture	**Non-agriculture**	**Agriculture**	**Non-agriculture**
FW_rmt_A	-0.105	0.002	-0.098	0.001
FW_rmt_R	-0.084	0.001	-0.078	0.001
FW_rmt_M	-0.063	0.001	-0.059	0.001

a) The labour market is segmented into agriculture (including the primary agriculture and fishing sectors) and non-agriculture (including processed foods, other manufacturing and services sectors.

Table A1.9	FW_rmt: EU exports and imports of red meat products and cattle (2020) (%, in difference from the BaU)															
	Volume of EU exports of red meat products to:								Volume of EU imports of red meat products from:							
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**ROE**	**MENA**	**WORLD**	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**ROE**	**MENA**	**WORLD**
FW_rmt_A	0.127	0.220	0.140	0.225	0.172	0.219	0.242	0.201	-4.300	-4.560	-4.360	-4.510	-4.480	-4.460	-4.450	-4.360
FW_rmt_R	0.102	0.176	0.112	0.180	0.138	0.175	0.194	0.161	-3.440	-3.650	-3.490	-3.610	-3.580	-3.570	-3.560	-3.490
FW_rmt_M	0.076	0.132	0.084	0.135	0.103	0.131	0.145	0.120	-2.580	-2.740	-2.620	-2.710	-2.690	-2.680	-2.670	-2.620
	Volume of EU exports of cattle to:								Volume of EU imports of cattle from:							
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**ROE**	**MENA**	**WORLD**	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**ROE**	**MENA**	**WORLD**
FW_rmt_A	0.161	0.343	0.212	0.343	0.358	0.231	0.348	0.299	-2.072	-2.303	-2.147	-2.251	-2.267	-2.263	-2.252	-2.270
FW_rmt_R	0.129	0.274	0.169	0.274	0.286	0.185	0.278	0.239	-1.658	-1.843	-1.718	-1.801	-1.814	-1.811	-1.802	-1.816
FW_rmt_M	0.097	0.206	0.127	0.206	0.215	0.139	0.209	0.180	-1.243	-1.383	-1.288	-1.351	-1.361	-1.359	-1.352	-1.363

Table A1.10	FW_rmt: GDP (2020) (2007 million USD, in difference from the BaU)								
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**
FW_rmt_A	-0.109	-1.820	-11.460	0.042	6.382	-698.128	2.635	1.593	-700.865
FW_rmt_R	-0.044	-1.213	-9.065	0.166	5.221	-559.156	2.411	1.252	-560.428
FW_rmt_M	-0.022	-0.607	-6.671	-0.083	3.481	-417.896	1.626	1.138	-419.033
BaU value in 2020	1,456,270	19,614,155	6,213,592	1,617,046	22,711,406	20,081,207	3,819,867	4,186,211	79,699,752

A.2 FW_v_f scenario

Table A2.1	FW_v_f: GDP per capita (2020) (2007 USD, in difference from the BaU)								
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**
FW_v_f_A	-0.081	-0.071	-0.137	-0.018	0.006	2.106	0.042	-0.046	0.124
FW_v_f_R	-0.066	-0.059	-0.110	-0.015	0.005	1.684	0.034	-0.037	0.099
FW_v_f_M	-0.049	-0.043	-0.083	-0.011	0.004	1.260	0.026	-0.028	0.075
BaU value in 2020	35,828	52,576	9,548	1,470	5,535	39,390	12,372	7,912	10,466

Table A2.2	FW_v_f: Per capita consumption by EU households (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_v_f_A	-9.450	0.113	0.089	0.132	0.081	0.039	0.117	0.191	0.021	0.132	0.026	0.043
FW_v_f_R	-7.559	0.090	0.071	0.106	0.065	0.031	0.094	0.153	0.017	0.106	0.021	0.035
FW_v_f_M	-5.669	0.068	0.053	0.079	0.049	0.023	0.070	0.114	0.013	0.079	0.016	0.026

Table A2.3	FW_v_f: Market prices for consumer goods in the EU (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_v_f_A	-1.030	-0.141	-0.060	-0.141	-0.066	-0.073	-0.120	-0.240	0.004	-0.155	0.009	0.015
FW_v_f_R	-0.822	-0.112	-0.048	-0.112	-0.053	-0.058	-0.096	-0.192	0.004	-0.124	0.007	0.012
FW_v_f_M	-0.615	-0.084	-0.036	-0.084	-0.040	-0.044	-0.072	-0.144	0.003	-0.093	0.005	0.009

Table A2.4	FW_v_f: Food security indicators (2020) (%, in difference from the BaU) a)										
Per capita food consumption by households										**excluding vegetables and fruits**	
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**	**EU27**	**WORLD**
FW_v_f_A	0.011	0.008	0.006	0.011	0.004	-0.508	0.012	0.017	-0.108	0.106	0.030
FW_v_f_R	0.009	0.006	0.005	0.009	0.003	-0.407	0.010	0.014	-0.086	0.084	0.024
FW_v_f_M	0.006	0.005	0.004	0.007	0.002	-0.305	0.007	0.010	-0.065	0.063	0.018
Market price of foods consumed by households											
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**		
FW_v_f_A	-0.026	-0.015	-0.045	-0.074	-0.018	-0.101	-0.040	-0.078	-0.061		
FW_v_f_R	-0.021	-0.012	-0.036	-0.059	-0.014	-0.081	-0.032	-0.063	-0.049		
FW_v_f_M	-0.016	-0.009	-0.027	-0.044	-0.011	-0.061	-0.024	-0.047	-0.037		
a) Foods consumed by households include all agri-food commodities consumed by households.											

Table A2.5	FW_v_f: Sectoral production in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_v_f_A	0.081	0.521	-6.591	0.409	0.137	0.198	0.159	0.262	0.083	-0.006	0.016	0.135	0.105	0.347	0.120	0.164	0.175	0.016	0.166
FW_v_f_R	0.065	0.416	-5.268	0.326	0.109	0.158	0.127	0.209	0.066	-0.005	0.013	0.108	0.084	0.277	0.096	0.131	0.140	0.013	0.133
FW_v_f_M	0.049	0.311	-3.947	0.244	0.082	0.119	0.095	0.157	0.049	-0.004	0.010	0.081	0.063	0.207	0.072	0.098	0.105	0.010	0.100

Table A2.6	FW_v_f: Market prices for producers in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_v_f_A	-0.576	-0.570	-1.278	-0.645	-0.664	-0.535	-0.412	-0.176	-0.063	0.011	0.015	-0.142	-0.076	-0.543	-0.107	-0.139	-0.265	0.005	-0.167
FW_v_f_R	-0.460	-0.456	-1.021	-0.515	-0.531	-0.428	-0.330	-0.141	-0.050	0.009	0.012	-0.114	-0.061	-0.434	-0.085	-0.111	-0.212	0.004	-0.133
FW_v_f_M	-0.345	-0.341	-0.765	-0.386	-0.398	-0.320	-0.247	-0.106	-0.038	0.006	0.009	-0.085	-0.046	-0.325	-0.064	-0.083	-0.159	0.003	-0.100

Table A2.7	FW_v_f: Change in land demand per sector in the EU (2020) (km²) a)								
Difference	**Scenario**	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**ctl**	**CER**	**TOTAL**
From 2012	BaU	-2,605	-9,212	-8,046	-11,969	-13,774	-2,534	-33,073	-81,213
From 2020 (BaU)	FW_v_f_A	0	517	-8,750	807	225	124	1,537	-5,540
From 2020 (BaU)	FW_v_f_R	0	413	-6,991	644	179	99	1,227	-4,429
From 2020 (BaU)	FW_v_f_M	0	309	-5,237	482	134	74	917	-3,321

a) This table reveals incremental changes in land use. The second row reports the difference in 2020 from 2012 in the reference BaU scenario. The third, fourth and fifth row report the results occurring in the red meat scenarios (ambitious, modest and realistic versions) in 2020 in difference from the BaU scenario result in 2020.

Table A2.8	FW_v_f: Real wage and employment impacts in the EU (2020) (%, in difference from the BaU)			
Scenario	**Employment**		**Real wage**	
	Agriculture	**Non-agriculture**	**Agriculture**	**Non-agriculture**
FW_v_f_A	-1.216	0.019	-1.227	0.009
FW_v_f_R	-0.972	0.015	-0.981	0.007
FW_v_f_M	-0.729	0.012	-0.735	0.006

a) The labour market is segmented into agriculture (including the primary agriculture and fishing sectors) and non-agriculture (including processed foods, other manufacturing and services sectors.

Table A2.9	FW_v_f: EU exports and imports of vegetables and fruits (2020) (%, in difference from the BaU)															
	Volume of EU exports of vegetables and fruits to:								**Volume of EU imports of vegetables and fruits from:**							
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**ROE**	**MENA**	**WORLD**	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**ROE**	**MENA**	**WORLD**
FW_v_f _A	3.656	2.992	3.237	2.708	3.468	2.596	3.180	2.807	-9.423	-9.455	-9.077	-9.273	-9.479	-9.413	-9.163	-9.224
FW_v_f_R	2.908	2.382	2.575	2.157	2.759	2.068	2.531	2.235	-7.559	-7.585	-7.276	-7.436	-7.605	-7.551	-7.346	-7.396
FW_v_f_M	2.169	1.777	1.921	1.610	2.058	1.544	1.888	1.668	-5.684	-5.704	-5.468	-5.591	-5.72	-5.678	-5.522	-5.56

Table A2.10	FW_v_f: GDP (2020) (2007 million USD, in difference from the BaU)								
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**
FW_rmt_A	-3.286	-26.386	-89.282	-19.887	23.787	1073.515	13.062	-24.462	947.062
FW_rmt_R	-2.677	-21.837	-71.665	-16.018	19.145	858.681	10.484	-19.342	756.772
FW_rmt_M	-1.980	-16.074	-53.706	-12.024	15.084	642.539	7.905	-14.677	567.067
BaU value in 2020	14,56,270	19,614,155	6,213,592	1,617,046	22,711,406	20,081,207	3,819,867	4,186,211	79,699,752

A.3 FW_mil scenario

Table A3.1	FW_mil: GDP per capita (2020) (2007 USD, in difference from the BaU)								
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**
FW_mil_A	0.001	0.000	-0.010	0.001	0.002	-1.687	0.014	0.004	-0.112
FW_mil_R	0.002	0.001	-0.008	0.001	0.001	-1.351	0.011	0.003	-0.090
FW_mil_M	0.001	-0.002	-0.006	0.000	0.002	-1.012	0.008	0.003	-0.067
BaU value in 2020	35,828	52,576	9,548	1,470	5,535	39,390	12,372	7,912	10,466

Table A3.2	FW_mil: Per capita consumption by EU households (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_mil_A	0.060	0.067	0.065	-3.399	0.066	0.058	0.073	0.129	-0.009	0.081	0.001	-0.005
FW_mil_R	0.048	0.054	0.052	-2.719	0.053	0.047	0.058	0.103	-0.007	0.065	0.001	-0.004
FW_mil_M	0.036	0.040	0.039	-2.038	0.040	0.035	0.044	0.077	-0.005	0.048	0.001	-0.003

Table A3.3	FW_mil: Market prices for consumer goods in the EU (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_mil_A	-0.170	-0.046	-0.024	-0.088	-0.025	-0.027	-0.041	-0.139	-0.005	-0.057	-0.002	-0.002
FW_mil_R	-0.136	-0.037	-0.019	-0.071	-0.020	-0.022	-0.033	-0.111	-0.004	-0.046	-0.001	-0.001
FW_mil_M	-0.102	-0.028	-0.014	-0.053	-0.015	-0.017	-0.025	-0.083	-0.003	-0.034	-0.001	-0.001

Table A3.4	FW_mil: Food security indicators (2020) (%, in difference from the BaU) a)										
Per capita food consumption by households										**excluding dairy**	
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**	**EU27**	**WORLD**
FW_mil_A	0.004	0.002	0.001	0.002	0.001	-0.406	0.003	0.003	-0.090	0.069	0.016
FW_mil_R	0.003	0.002	0.001	0.002	0.001	-0.324	0.003	0.002	-0.072	0.055	0.013
FW_mil_M	0.002	0.001	0.001	0.001	0.001	-0.243	0.002	0.002	-0.054	0.041	0.010
Market price of foods consumed by households											
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**		
FW_mil_A	-0.007	-0.001	-0.006	-0.011	-0.002	-0.051	-0.011	-0.010	-0.024		
FW_mil_R	-0.006	-0.001	-0.004	-0.009	-0.002	-0.041	-0.008	-0.008	-0.020		
FW_mil_M	-0.004	0.000	-0.003	-0.006	-0.001	-0.030	-0.006	-0.006	-0.015		
a) Foods consumed by households include all agri-food commodities consumed by households											

Table A3.5	FW_mil: Sectoral production in the EU (2020) (%, in difference from the BaU)																			
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_mil_A	-0.052	0.166	0.155	0.054	-1.936	0.088	0.071	0.083	0.003	0.006	0.014	-2.467	-0.083	-0.042	0.071	0.085	-0.024	-0.008	0.088
FW_mil_R	-0.042	0.133	0.124	0.043	-1.548	0.071	0.057	0.066	0.002	0.005	0.011	-1.973	-0.067	-0.033	0.057	0.068	-0.019	-0.006	0.071
FW_mil_M	-0.031	0.099	0.093	0.033	-1.161	0.053	0.043	0.050	0.002	0.004	0.008	-1.479	-0.050	-0.025	0.043	0.051	-0.014	-0.005	0.053

Table A3.6	FW_mil: Market prices for producers in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_mil_A	-0.182	-0.179	-0.218	-0.202	-0.360	-0.185	-0.132	-0.059	-0.025	-0.002	-0.002	-0.087	-0.031	-0.191	-0.043	-0.049	-0.152	-0.005	-0.062
FW_mil_R	-0.146	-0.144	-0.175	-0.162	-0.288	-0.148	-0.106	-0.047	-0.020	-0.002	-0.001	-0.070	-0.024	-0.153	-0.034	-0.039	-0.121	-0.004	-0.050
FW_mil_M	-0.110	-0.108	-0.131	-0.122	-0.216	-0.111	-0.080	-0.035	-0.015	-0.001	-0.001	-0.052	-0.018	-0.115	-0.026	-0.030	-0.091	-0.003	-0.037

Table A3.7	FW_mil: Change in land demand per sector in the EU (2020) (km^2) a)								
Difference	**Scenario**	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**ctl**	**CER**	**TOTAL**
From 2012	BaU	-2,605	-9,212	-8,046	-11,969	-13,774	-2,534	-33,073	-81,213
From 2020 (BaU)	FW_mil_A	8	300	319	354	-7,547	263	260	-6,043
From 2020 (BaU)	FW_mil_R	6	240	255	284	-6,034	210	208	-4,831
From 2020 (BaU)	FW_mil_M	5	180	191	213	-4,523	158	156	-3,620

a) This table reveals incremental changes in land use. The second row reports the difference in 2020 from 2012 in the reference BaU scenario. The third, fourth and fifth row report the results occurring in the red meat scenarios (ambitious, modest and realistic versions) in 2020 in difference from the BaU scenario result in 2020.

Table A3.8	FW_mil: Real wage and employment impacts in the EU (2020) (%, in difference from the BaU) a)			
Scenario	**Employment**		**Real wage**	
	Agriculture	**Non-agriculture**	**Agriculture**	**Non-agriculture**
FW_mil_A	-0.217	0.0035	-0.2197	0.0026
FW_mil_R	-0.1735	0.0028	-0.1756	0.0021
FW_mil_M	-0.1301	0.0021	-0.1318	0.0015

a) The labour market is segmented into agriculture (including the primary agriculture and fishing sectors) and non-agriculture (including processed foods, other manufacturing and services sectors.

Table A3.9	FW_mil: EU exports and imports of dairy products (2020) (%, in difference from the BaU)															
	Volume of EU exports of dairy products to:								Volume of EU imports of dairy products from:							
Scenario	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD
FW_mil_A	0.370	0.443	0.479	0.407	0.475	0.312	0.422	0.408	-2.714	-2.816	-2.749	-2.814	-2.764	-2.763	-2.745	-2.747
FW_mil_R	0.296	0.355	0.383	0.326	0.380	0.250	0.338	0.327	-2.172	-2.253	-2.200	-2.252	-2.212	-2.211	-2.197	-2.198
FW_mil_M	0.222	0.266	0.288	0.244	0.285	0.188	0.253	0.245	-1.629	-1.691	-1.651	-1.690	-1.659	-1.659	-1.649	-1.649

Table A3.10	FW_mil: GDP (2020) (2007 million USD, in difference from the BaU)								
Scenario	OCE	NAM	CSA	SSA	ASIA	EU27	ROE	MENA	WORLD
FW_mil_A	0.022	0.000	-6.671	0.790	8.122	-859.989	4.317	2.162	-851.247
FW_mil_R	0.087	0.303	-5.131	0.666	5.221	-688.645	3.308	1.820	-682.371
FW_mil_M	0.022	-0.910	-3.934	0.333	6.382	-515.994	2.523	1.593	-509.985
BaU value in 2020	1,456,270	19,614,155	6,213,592	1,617,046	22,711,406	20,081,207	3,819,867	4,186,211	79,699,752

A.4 FW_wmt scenario

Table A4.1	FW_wmt: GDP per capita (2020) (2007 USD, in difference from the BaU)								
Scenario	OCE	NAM	CSA	SSA	ASIA	EU27	ROE	MENA	WORLD
FW_wmt_A	0.012	-0.007	-0.036	0.001	0.000	-0.950	0.020	0.003	-0.066
FW_wmt_R	0.008	-0.005	-0.028	0.001	0.000	-0.762	0.015	0.003	-0.053
FW_wmt_M	0.008	-0.004	-0.021	0.001	0.000	-0.570	0.012	0.002	-0.040
BaU value in 2020	35,828	52,576	9,548	1,470	5,535	39,390	12,372	7,912	10,466

Table A4.2	FW_wmt: Per capita consumption by EU households (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_wmt_A	0.078	0.088	0.085	0.107	0.086	0.075	0.098	0.158	0.009	-5.375	0.019	0.012
FW_wmt_R	0.062	0.070	0.068	0.086	0.069	0.060	0.079	0.126	0.007	-4.299	0.015	0.010
FW_wmt_M	0.046	0.053	0.051	0.064	0.051	0.045	0.059	0.095	0.006	-3.224	0.011	0.007

Table A4.3	FW_wmt: Market prices for consumer goods in the EU (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_wmt_A	-0.196	-0.054	-0.029	-0.058	-0.029	-0.035	-0.055	-0.158	-0.007	-0.121	-0.002	-0.003
FW_wmt_R	-0.157	-0.043	-0.023	-0.047	-0.023	-0.028	-0.044	-0.127	-0.006	-0.097	-0.002	-0.002
FW_wmt_M	-0.118	-0.032	-0.017	-0.035	-0.017	-0.021	-0.033	-0.095	-0.004	-0.073	-0.001	-0.002

Table A4.4	FW_wmt: Food security indicators (2020) (%, in difference from the BaU) a)										
Per capita food consumption by households										**excluding white meat**	
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**	**EU27**	**WORLD**
FW_wmt_A	0.004	0.003	0.002	0.003	0.002	-0.589	0.004	0.004	-0.130	0.091	0.021
FW_wmt_R	0.003	0.002	0.002	0.003	0.002	-0.471	0.004	0.003	-0.104	0.073	0.017
FW_wmt_M	0.002	0.002	0.001	0.002	0.001	-0.353	0.003	0.002	-0.078	0.055	0.013
Market price of foods consumed by households											
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**		
FW_wmt_A	-0.007	-0.001	-0.013	-0.013	-0.005	-0.050	-0.013	-0.013	-0.030		
FW_wmt_R	-0.005	-0.001	-0.011	-0.011	-0.004	-0.040	-0.011	-0.011	-0.024		
FW_wmt_M	-0.004	-0.001	-0.008	-0.008	-0.003	-0.030	-0.008	-0.008	-0.018		

a) Foods consumed by households include all agri-food commodities consumed by households.

Table A4.5	FW_wmt: Sectoral production in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_wmt_A	0.029	0.166	0.177	0.083	-0.016	-2.774	-0.809	0.069	-0.027	0.016	0.020	0.049	0.030	-0.360	0.086	0.107	0.017	0.008	-4.430
FW_wmt_R	0.023	0.133	0.141	0.067	-0.013	-2.219	-0.647	0.055	-0.022	0.013	0.016	0.039	0.024	-0.288	0.069	0.085	0.013	0.006	-3.543
FW_wmt_M	0.017	0.099	0.106	0.050	-0.010	-1.664	-0.485	0.041	-0.016	0.010	0.012	0.029	0.018	-0.216	0.052	0.064	0.010	0.005	-2.657

Table A4.6	FW_wmt: Market prices for producers in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_wmt_A	-0.203	-0.202	-0.251	-0.230	-0.243	-0.369	-0.179	-0.068	-0.030	-0.003	-0.003	-0.059	-0.035	-0.228	-0.053	-0.065	-0.173	-0.007	-0.125
FW_wmt_R	-0.162	-0.162	-0.201	-0.184	-0.194	-0.296	-0.143	-0.054	-0.024	-0.003	-0.003	-0.047	-0.028	-0.183	-0.043	-0.052	-0.139	-0.006	-0.100
FW_wmt_M	-0.122	-0.121	-0.151	-0.138	-0.146	-0.222	-0.107	-0.041	-0.018	-0.002	-0.002	-0.035	-0.021	-0.137	-0.032	-0.039	-0.104	-0.005	-0.075

Table A4.7	FW_wmt: Change in land demand per sector in the EU (2020) (km^2) a)								
Difference:	**Scenario**	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**ctl**	**CER**	**TOTAL**
From 2012	BaU	-2,605	-9,212	-8,046	-11,969	-13,774	-2,534	-33,073	-81,213
From 2020 (BaU)	FW_wmt_A	4	185	219	183	-103	-1,350	-2,143	-3,005
From 2020 (BaU)	FW_wmt_R	4	148	175	146	-82	-1,080	-1,714	-2,403
From 2020 (BaU)	FW_wmt_M	3	111	131	110	-61	-810	-1,285	-1,801

a) This table reveals incremental changes in land use. The second row reports the difference in 2020 from 2012 in the reference BaU scenario. The third, fourth and fifth row report the results occurring in the red meat scenarios (ambitious, modest and realistic versions) in 2020 in difference from the BaU scenario result in 2020.

Table A4.8	FW_wmt: Real wage and employment impacts in the EU (2020) (%, in difference from the BaU) a)			
Scenario	Employment		Real wage	
	Agriculture	Non-agriculture	Agriculture	Non-agriculture
FW_wmt_A	-0.376	0.006	-0.375	0.006
FW_wmt_R	-0.301	0.005	-0.300	0.005
FW_wmt_M	-0.225	0.004	-0.225	0.004

a) The labour market is segmented into agriculture (including the primary agriculture and fishing sectors) and non-agriculture (including processed foods, other manufacturing and services sectors.

Table A4.9	FW_wmt: EU exports and imports of white meat products, live chicken and pigs and cereals (2020) (%, in difference from the BaU)															
	Volume of EU exports of white meat products to:								Volume of EU imports of white meat products from:							
Scenario	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD
FW_wmt_A	0.760	0.851	0.853	0.762	0.808	0.719	0.810	0.770	-4.847	-4.939	-4.668	-4.800	-4.742	-4.819	-4.712	-4.707
FW_wmt_R	0.608	0.680	0.682	0.609	0.646	0.575	0.647	0.615	-3.880	-3.954	-3.736	-3.842	-3.796	-3.858	-3.772	-3.768
FW_wmt_M	0.455	0.509	0.511	0.456	0.484	0.431	0.485	0.461	-2.912	-2.968	-2.803	-2.884	-2.848	-2.895	-2.83	-2.827
	Volume of EU exports of live chicken and pigs to:								Volume of EU imports of live chicken and pigs from:							
Scenario	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD
FW_wmt_A	0.748	0.798	0.742	0.653	0.725	0.484	0.559	0.644	-3.198	-3.273	-3.160	-3.215	-3.231	-3.206	-3.2	-3.212
FW_wmt_R	0.598	0.637	0.593	0.522	0.580	0.387	0.447	0.515	-2.560	-2.620	-2.529	-2.573	-2.586	-2.566	-2.561	-2.571
FW_wmt_M	0.448	0.477	0.444	0.391	0.434	0.290	0.335	0.386	-1.921	-1.966	-1.898	-1.931	-1.941	-1.925	-1.921	-1.929
	Volume of EU exports of cereals to:								Volume of EU imports of cereals from:							
Scenario	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD
FW_wmt_A	1.176	1.168	1.123	1.017	1.171	0.705	0.999	0.974	-1.125	-1.152	-1.03	-1.077	-1.15	-1.078	-1.066	-1.075
FW_wmt_R	0.939	0.933	0.897	0.813	0.935	0.563	0.798	0.778	-0.901	-0.922	-0.825	-0.862	-0.92	-0.863	-0.853	-0.861
FW_wmt_M	0.703	0.699	0.672	0.609	0.701	0.422	0.598	0.583	-0.676	-0.692	-0.619	-0.647	-0.691	-0.647	-0.64	-0.646

Table A4.10	FW_wmt: GDP (2020) (2007 million USD, in difference from the BaU)								
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**
FW_wmt_A	0.479	-2.730	-23.090	0.915	0.000	-484.275	6.055	1.593	-501.053
FW_wmt_R	0.326	-1.820	-18.472	0.832	-0.580	-388.467	4.653	1.365	-402.162
FW_wmt_M	0.305	-1.516	-13.854	0.624	-1.740	-290.369	3.588	0.796	-302.167
BaU value in 2020	1,456,270	19,614,155	6,213,592	1,617,046	22,711,406	20,081,207	3,819,867	4,186,211	79,699,752

A.5 FW_sgr scenario

Table A5.1	FW_sgr: GDP per capita (2020) (2007 USD, in difference from the BaU)								
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**
FW_sgr_A	-0.001	0.002	-0.003	-0.001	0.001	-0.963	-0.002	0.001	-0.064
FW_sgr_R	0.001	0.004	-0.002	-0.001	0.000	-0.770	-0.001	0.001	-0.052
FW_sgr_M	0.000	0.006	-0.001	-0.001	-0.001	-0.576	-0.001	0.000	-0.039
BaU value in 2020	35,828	52,576	9,548	1,470	5,535	39,390	12,372	7,912	10,466

Table A5.2	FW_sgr: Per capita consumption by EU households (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_sgr_A	0.015	0.014	0.015	0.018	-8.467	0.016	0.015	0.016	-0.001	0.016	0.002	-0.001
FW_sgr_R	0.012	0.011	0.012	0.014	-6.773	0.013	0.012	0.013	-0.001	0.013	0.001	-0.001
FW_sgr_M	0.009	0.009	0.009	0.011	-5.079	0.010	0.009	0.010	-0.001	0.010	0.001	-0.001

Table A5.3	FW_sgr: Market prices for consumer goods in the EU (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_sgr_A	-0.013	-0.004	-0.002	-0.004	-0.042	-0.002	-0.003	-0.007	-0.001	-0.004	0.000	0.000
FW_sgr_R	-0.010	-0.003	-0.002	-0.003	-0.034	-0.002	-0.003	-0.005	-0.001	-0.004	0.000	0.000
FW_sgr_M	-0.008	-0.002	-0.001	-0.003	-0.025	-0.001	-0.002	-0.004	-0.001	-0.003	0.000	0.000

Table A5.4	FW_sgr: Food security indicators (2020) (%, in difference from the BaU) a)										
Per capita food consumption by households										**excluding sugar**	
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**	**EU27**	**WORLD**
FW_sgr_A	0.000	0.000	0.000	0.000	0.000	-0.101	0.000	0.000	-0.022	0.015	0.004
FW_sgr_R	0.000	0.000	0.000	0.000	0.000	-0.081	0.000	0.000	-0.018	0.012	0.003
FW_sgr_M	0.000	0.000	0.000	0.000	0.000	-0.061	0.000	0.000	-0.013	0.009	0.002
Market price of foods consumed by households											
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**		
FW_sgr_A	-0.001	0.000	-0.001	-0.004	0.000	-0.006	-0.002	-0.001	-0.004		
FW_sgr_R	0.000	0.000	-0.001	-0.003	0.000	-0.004	-0.001	-0.001	-0.003		
FW_sgr_M	0.000	0.000	-0.001	-0.002	0.000	-0.003	-0.001	0.000	-0.002		
a) Foods consumed by households include all agri-food commodities consumed by households.											

Table A5.5	FW_sgr: Sectoral production in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_sgr_A	-3.258	0.020	0.021	0.017	0.015	0.014	0.013	0.016	0.011	0.003	0.004	0.015	-4.985	0.017	0.015	0.015	0.001	0.000	0.015
FW_sgr_R	-2.606	0.016	0.017	0.013	0.012	0.011	0.010	0.013	0.009	0.002	0.003	0.012	-3.988	0.013	0.012	0.012	0.001	0.000	0.012
FW_sgr_M	-1.955	0.012	0.013	0.010	0.009	0.009	0.008	0.010	0.007	0.002	0.002	0.009	-2.991	0.010	0.009	0.009	0.001	0.000	0.009

Table A5.6	FW_sgr: Market prices for producers in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_sgr_A	-0.217	-0.013	-0.016	-0.015	-0.016	-0.013	-0.010	-0.005	-0.002	-0.001	-0.001	-0.004	-0.038	-0.013	-0.003	-0.004	-0.007	-0.001	-0.005
FW_sgr_R	-0.173	-0.011	-0.013	-0.012	-0.013	-0.011	-0.008	-0.004	-0.002	0.000	0.000	-0.003	-0.030	-0.010	-0.003	-0.003	-0.006	-0.001	-0.004
FW_sgr_M	-0.130	-0.008	-0.010	-0.009	-0.009	-0.008	-0.006	-0.003	-0.001	0.000	0.000	-0.003	-0.023	-0.008	-0.002	-0.002	-0.004	-0.001	-0.003

Table A5.7	FW_sgr: Change in land demand per sector in the EU (2020) (km^2) a)								
Difference:	**Scenario**	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**ctl**	**CER**	**TOTAL**
From 2012	BaU	-2,605	-9,212	-8,046	-11,969	-13,774	-2,534	-33,073	-81,213
From 2020 (BaU)	FW_sgr_A	-715	29	34	53	78	29	124	-368
From 2020 (BaU)	FW_sgr_R	-572	23	27	42	63	23	99	-295
From 2020 (BaU)	FW_sgr_M	-429	17	20	32	47	18	74	-221

a) This table reveals incremental changes in land use. The second row reports the difference in 2020 from 2012 in the reference BaU scenario. The third, fourth and fifth row report the results occurring in the red meat scenarios (ambitious, modest and realistic versions) in 2020 in difference from the BaU scenario result in 2020.

Table A5.8	FW_sgr: Real wage and employment impacts in the EU (2020) (%, in difference from the BaU) a)			
Scenario	**Employment**		**Real wage**	
	Agriculture	**Non-agriculture**	**Agriculture**	**Non-agriculture**
FW_sgr_A	-0.018	0.000	-0.021	0.000
FW_sgr_R	-0.014	0.000	-0.017	0.000
FW_sgr_M	-0.011	0.000	-0.012	0.000

a) The labour market is segmented into agriculture (including the primary agriculture and fishing sectors) and non-agriculture (including processed foods, other manufacturing and services sectors.

Table A5.9	FW_sgr: EU exports and imports of sugar, sugar cane and beet (2020) (%, in difference from the BaU)															
	Volume of EU exports of sugar to:								Volume of EU imports of sugar from:							
Scenario	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD
FW_sgr_A	0.077	0.135	0.117	0.118	0.142	0.104	0.130	0.121	-4.660	-4.670	-4.610	-4.600	-4.620	-4.600	-4.63	-4.61
FW_sgr_R	0.062	0.108	0.093	0.095	0.113	0.083	0.104	0.097	-3.730	-3.740	-3.690	-3.680	-3.690	-3.680	-3.7	-3.69
FW_sgr_M	0.046	0.081	0.070	0.071	0.085	0.062	0.078	0.073	-2.800	-2.800	-2.760	-2.760	-2.770	-2.760	-2.78	-2.76
	Volume of EU exports of sugar cane and beet to:								Volume of EU imports of sugar cane and beet from:							
Scenario	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD
FW_sgr_A	1.034	1.042	1.004	0.978	1.043	0.524	1.013	0.554	-2.013	-2.022	-1.958	-1.917	-1.995	-1.893	-2.007	-1.947
FW_sgr_R	0.826	0.832	0.802	0.781	0.833	0.419	0.809	0.443	-1.612	-1.619	-1.568	-1.535	-1.597	-1.515	-1.607	-1.559
FW_sgr_M	0.619	0.623	0.601	0.585	0.624	0.314	0.606	0.332	-1.210	-1.215	-1.177	-1.152	-1.199	-1.137	-1.206	-1.17

Table A5.10	FW_sgr: GDP (2020) (2007 million USD, in difference from the BaU)								
Scenario	OCE	NAM	CSA	SSA	ASIA	EU27	ROE	MENA	WORLD
FW_sgr_A	-0.022	0.910	-1.710	-1.539	2.901	-491.142	-0.505	0.341	-490.766
FW_sgr_R	0.022	1.516	-1.539	-1.207	0.000	-392.391	-0.336	0.341	-393.593
FW_sgr_M	0.000	2.123	-0.855	-0.998	-2.321	-293.639	-0.336	0.000	-296.027
BaU value in 2020	1,456,270	19,614,155	6,213,592	1,617,046	22,711,406	20,081,207	3,819,867	4,186,211	79,699,752

A.6 FW_pcr_FBT scenario

Table A6.1	FW_pcr_FBT: GDP per capita (2020) (2007 USD, in difference from the BaU)								
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**
FW_pcr_FBT_A	0.322	0.037	-0.073	0.027	0.042	-45.789	-0.013	0.002	-3.042
FW_pcr_FBT_R	0.255	0.029	-0.058	0.022	0.034	-36.630	-0.011	0.002	-2.433
FW_pcr_FBT_M	0.194	0.023	-0.043	0.016	0.025	-27.473	-0.009	0.001	-1.825
BaU value in 2020	35,828	52,576	9,548	1,470	5,535	39,390	12,372	7,912	10,466

Table A6.2	FW_pcr_FBT: Per capita consumption by EU households (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_pcr_FBT_A	0.950	0.791	-11.777	1.074	0.953	-11.611	0.886	1.464	-0.522	0.920	-0.331	-0.540
FW_pcr_FBT_R	0.757	0.630	-9.407	0.857	0.760	-9.271	0.707	1.169	-0.420	0.734	-0.266	-0.434
FW_pcr_FBT_M	0.566	0.471	-7.045	0.641	0.568	-6.940	0.529	0.875	-0.317	0.549	-0.201	-0.327

Table A6.3	FW_pcr_FBT: Market prices for consumer goods in the EU (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_pcr_FBT_A	-0.776	-0.279	-0.195	-0.289	-0.169	-0.207	-0.237	-1.343	-0.098	-0.302	-0.058	-0.074
FW_pcr_FBT_R	-0.621	-0.223	-0.156	-0.232	-0.135	-0.165	-0.190	-1.077	-0.079	-0.242	-0.046	-0.059
FW_pcr_FBT_M	-0.465	-0.167	-0.117	-0.174	-0.101	-0.123	-0.142	-0.810	-0.059	-0.181	-0.035	-0.044

Table A6.4	FW_pcr_FBT: Food security indicators (2020) (%, in difference from the BaU) a)										
Per capita food consumption by households										**excluding processed rice and 'other food'**	
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**	**EU27**	**WORLD**
FW_pcr_FBT_A	0.024	0.015	0.012	0.028	0.014	-6.147	0.024	0.020	-1.364	0.989	0.206
FW_pcr_FBT_R	0.019	0.012	0.010	0.023	0.011	-4.911	0.019	0.016	-1.090	0.789	0.165
FW_pcr_FBT_M	0.014	0.009	0.007	0.017	0.008	-3.678	0.015	0.012	-0.816	0.590	0.123
Market price of foods consumed by households											
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**		
FW_pcr_FBT_A	-0.029	0.020	-0.042	-0.120	-0.021	-0.447	-0.090	-0.067	-0.261		
FW_pcr_FBT_R	-0.023	0.016	-0.034	-0.096	-0.017	-0.354	-0.072	-0.053	-0.209		
FW_pcr_FBT_M	-0.018	0.012	-0.025	-0.072	-0.012	-0.264	-0.054	-0.040	-0.156		
a) Foods consumed by households include all agri-food commodities consumed by households.											

Table A6.5	FW_pcr_FBT: Sectoral production in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_pcr_FBT_A	-0.298	-1.694	-0.232	-1.759	-0.635	-0.429	-0.643	-1.865	-7.736	0.108	0.234	0.328	-0.413	-1.596	-8.334	0.327	-0.493	-0.387	0.455
FW_pcr_FBT_R	-0.239	-1.351	-0.185	-1.403	-0.508	-0.343	-0.514	-1.489	-6.179	0.086	0.188	0.261	-0.330	-1.274	-6.653	0.261	-0.394	-0.311	0.363
FW_pcr_FBT_M	-0.179	-1.010	-0.139	-1.049	-0.381	-0.258	-0.385	-1.114	-4.628	0.065	0.141	0.195	-0.248	-0.954	-4.978	0.195	-0.295	-0.235	0.271

Table A6.6	FW_pcr_FBT: Market prices for producers in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_pcr_FBT_A	-0.785	-0.919	-0.992	-0.998	-0.979	-0.819	-0.630	-0.360	-0.196	-0.077	-0.079	-0.295	-0.208	-0.893	-0.273	-0.286	-1.451	-0.100	-0.327
FW_pcr_FBT_R	-0.628	-0.736	-0.794	-0.799	-0.783	-0.656	-0.504	-0.288	-0.157	-0.062	-0.063	-0.236	-0.166	-0.715	-0.218	-0.229	-1.164	-0.080	-0.262
FW_pcr_FBT_M	-0.471	-0.552	-0.595	-0.599	-0.588	-0.492	-0.378	-0.216	-0.118	-0.046	-0.047	-0.177	-0.125	-0.536	-0.164	-0.172	-0.875	-0.060	-0.197

Table A6.7	FW_pcr_FBT: Change in land demand per sector in the EU (2020) (km^2) a)								
Difference:	**Scenario**	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**ctl**	**CER**	**TOTAL**
From 2012	BaU	-2605	-9212	-8046	-11969	-13774	-2534	-33073	-81213
From 2020 (BaU)	FW_pcr_FBT_A	-30	-1821	-93	-3978	-1950	-798	-8363	-17033
From 2020 (BaU)	FW_pcr_FBT_R	-24	-1451	-74	-3170	-1557	-637	-6672	-13585
From 2020 (BaU)	FW_pcr_FBT_M	-18	-1084	-55	-2368	-1166	-477	-4989	-10157

a) This table reveals incremental changes in land use. The second row reports the difference in 2020 from 2012 in the reference BaU scenario. The third, fourth and fifth row report the results occurring in the red meat scenarios (ambitious, modest and realistic versions) in 2020 in difference from the BaU scenario result in 2020.

Table A6.8	FW_pcr_FBT: Real wage and employment impacts in the EU (2020) (%, in difference from the BaU) a)			
Scenario	**Employment**		**Real wage**	
	Agriculture	**Non-agriculture**	**Agriculture**	**Non-agriculture**
FW_pcr_FBT_A	-1.02	0.016	-1.118	-0.001
FW_pcr_FBT_R	-0.815	0.013	-0.893	-0.001
FW_pcr_FBT_M	-0.61	0.01	-0.669	-0.001

a) The labour market is segmented into agriculture (including the primary agriculture and fishing sectors) and non-agriculture (including processed foods, other manufacturing and services sectors.

Table A6.9	FW_pcr_FBT: EU exports and imports of 'other food' and processed rice (2020) (%, in difference from the BaU)															
	Volume of EU exports of 'other food' to:								Volume of EU imports of 'other food' from:							
Scenario	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD
FW_pcr_FBT_A	0.467	0.541	0.445	0.296	0.480	0.183	0.399	0.396	-8.350	-8.490	-8.270	-8.160	-8.320	-8.120	-8.26	-8.27
FW_pcr_FBT_R	0.374	0.433	0.356	0.237	0.384	0.147	0.319	0.317	-6.680	-6.790	-6.610	-6.520	-6.650	-6.490	-6.6	-6.61
FW_pcr_FBT_M	0.280	0.325	0.267	0.178	0.288	0.110	0.240	0.238	-5.000	-5.090	-4.960	-4.890	-4.980	-4.860	-4.95	-4.95
	Volume of EU exports of processed rice to:								Volume of EU imports of processed rice from:							
Scenario	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD
FW_pcr_FBT_A	1.046	1.162	1.034	1.074	1.242	0.848	0.939	0.959	-9.690	-9.790	-9.310	-9.180	-9.440	-9.260	-9.25	-9.42
FW_pcr_FBT_R	0.837	0.929	0.827	0.859	0.993	0.679	0.751	0.767	-7.750	-7.830	-7.440	-7.330	-7.550	-7.400	-7.39	-7.53
FW_pcr_FBT_M	0.627	0.696	0.620	0.644	0.744	0.509	0.563	0.575	-5.810	-5.870	-5.570	-5.490	-5.650	-5.540	-5.54	-5.64

Table A6.10	FW_pcr_FBT: GDP (2020) (2007 million USD, in difference from the BaU)								
Scenario	OCE	NAM	CSA	SSA	ASIA	EU27	ROE	MENA	WORLD
FW_pcr_FBT_A	13	14	-47	30	172	-23344	-4	1	-23165
FW_pcr_FBT_R	10	11	-38	24	138	-18675	-3	1	-18531
FW_pcr_FBT_M	8	8	-28	18	102	-14006	-3	1	-13900
BaU value in 2020	1,456,270	19,614,155	6,213,592	1,617,046	22,711,406	20,081,207	3,819,867	4,186,211	79,699,752

A.7 FW_ret scenario

Table A7.1	FW_ret: GDP per capita (2020) (2007 USD, in difference from the BaU)								
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**
FW_ret_A	-0.005	-0.002	-0.008	0.000	0.000	3.164	0.010	0.002	0.212
FW_ret_R	-0.004	-0.002	-0.007	0.000	0.000	2.527	0.008	0.002	0.169
FW_ret_M	-0.004	-0.002	-0.004	0.000	0.000	1.915	0.005	0.001	0.128
BaU value in 2020	35,828	52,576	9,548	1,470	5,535	39,390	12,372	7,912	10,466

Table A7.2	FW_ret: Per capita consumption by EU households (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_ret_A	-0.012	-0.009	-0.014	-0.011	-0.015	-0.013	-0.010	0.312	0.041	-0.009	-0.007	0.017
FW_ret_R	-0.009	-0.007	-0.011	-0.009	-0.012	-0.011	-0.008	0.252	0.033	-0.007	-0.005	0.013
FW_ret_M	-0.007	-0.006	-0.008	-0.006	-0.009	-0.008	-0.006	0.191	0.025	-0.006	-0.004	0.010

Table A7.3	FW_ret: Market prices for consumer goods in the EU (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_ret_A	-0.034	-0.008	-0.003	-0.010	-0.002	-0.003	-0.008	-0.518	-0.058	-0.010	0.004	0.006
FW_ret_R	-0.027	-0.006	-0.003	-0.008	-0.002	-0.002	-0.007	-0.418	-0.046	-0.008	0.003	0.005
FW_ret_M	-0.021	-0.005	-0.002	-0.006	-0.002	-0.002	-0.005	-0.317	-0.035	-0.006	0.002	0.004

Table A7.4	FW_ret: Food security indicators (2020) (%, in difference from the BaU) a)										
Per capita food consumption by households											
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**		
FW_ret_A	0.002	0.001	0.001	0.001	0.001	-0.008	0.002	0.002	-0.001		
FW_ret_R	0.002	0.001	0.000	0.001	0.001	-0.006	0.002	0.001	-0.001		
FW_ret_M	0.001	0.001	0.000	0.001	0.000	-0.005	0.001	0.001	-0.001		
Market price of foods consumed by households											
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**		
FW_ret_A	-0.003	0.000	-0.003	-0.005	-0.002	-0.015	-0.006	-0.005	-0.006		
FW_ret_R	-0.003	0.000	-0.002	-0.004	-0.002	-0.012	-0.005	-0.004	-0.005		
FW_ret_M	-0.002	0.000	-0.002	-0.003	-0.001	-0.009	-0.004	-0.003	-0.004		
a) Foods consumed by households include all agri-food commodities consumed by households.											

Table A7.5	FW_ret: Sectoral production in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_ret_A	-0.181	-0.035	-0.020	-0.029	-0.048	-0.089	-0.101	-0.067	-0.141	-0.007	0.004	-0.037	-0.285	-0.043	-0.178	-0.131	-0.312	0.036	-0.125
FW_ret_R	-0.146	-0.028	-0.016	-0.023	-0.036	-0.071	-0.081	-0.054	-0.113	-0.006	0.003	-0.026	-0.229	-0.034	-0.142	-0.105	-0.251	0.029	-0.100
FW_ret_M	-0.110	-0.021	-0.012	-0.017	-0.030	-0.054	-0.061	-0.041	-0.085	-0.005	0.002	-0.024	-0.173	-0.026	-0.107	-0.079	-0.190	0.022	-0.075

Table A7.6	FW_ret: Market prices for producers in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_ret_A	-0.043	-0.036	-0.044	-0.039	-0.043	-0.039	-0.028	-0.010	-0.004	0.004	0.006	-0.010	-0.003	-0.036	-0.004	-0.010	-0.568	-0.059	-0.011
FW_ret_R	-0.035	-0.029	-0.035	-0.031	-0.034	-0.031	-0.022	-0.008	-0.003	0.003	0.005	-0.008	-0.002	-0.029	-0.003	-0.008	-0.459	-0.047	-0.009
FW_ret_M	-0.026	-0.022	-0.027	-0.024	-0.027	-0.024	-0.017	-0.006	-0.002	0.003	0.004	-0.006	-0.002	-0.022	-0.003	-0.006	-0.348	-0.036	-0.007

Table A7.7	FW_ret: Change in land demand per sector in the EU (2020) (km^2) a)								
Difference:	**Scenario**	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**ctl**	**CER**	**TOTAL**
From 2012	BaU	-2,605	-9,212	-8,046	-11,969	-13,774	-2,534	-33,073	-81,213
From 2020 (BaU)	FW_ret_A	-38	-34	-18	-56	-171	-156	-213	-686
From 2020 (BaU)	FW_ret_R	-31	-28	-15	-45	-128	-126	-171	-544
From 2020 (BaU)	FW_ret_M	-23	-20	-11	-34	-107	-94	-129	-418

a) This table reveals incremental changes in land use. The second row reports the difference in 2020 from 2012 in the reference BaU scenario. The third, fourth and fifth row report the results occurring in the red meat scenarios (ambitious, modest and realistic versions) in 2020 in difference from the BaU scenario result in 2020.

Table A7.8	FW_ret: Real wage and employment impacts in the EU (2020) (%, in difference from the BaU) a)			
Scenario	**Employment**		**Real wage**	
	Agriculture	**Non-agriculture**	**Agriculture**	**Non-agriculture**
FW_ret_A	-0.055	0.001	-0.047	0.011
FW_ret_R	-0.044	0.001	-0.037	0.009
FW_ret_M	-0.033	0.001	-0.028	0.007

a) The labour market is segmented into agriculture (including the primary agriculture and fishing sectors) and non-agriculture (including processed foods, other manufacturing and services sectors.

Table A7.9	FW_ret: EU exports and imports of agri-food commodities (2020) (%, in difference from the BaU) a)															
	Volume of EU exports of retail to:									Volume of EU imports of retail from:						
Scenario	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD		OCE	NAM	CSA	SSA	ASIA	ROE	MENA
FW_ret_A	0.186	0.199	0.182	0.168	0.159	0.165	0.176	0.168	FW_ret_A	-0.078	-0.081	-0.076	-0.078	-0.080	-0.080	-0.0802
FW_ret_R	0.149	0.159	0.145	0.135	0.127	0.132	0.140	0.134	FW_ret_R	-0.062	-0.065	-0.061	-0.062	-0.064	-0.064	-0.0641
FW_ret_M	0.113	0.120	0.110	0.102	0.096	0.100	0.106	0.102	FW_ret_M	-0.047	-0.049	-0.046	-0.047	-0.049	-0.048	-0.0486
	Volume of EU exports of agri-food commodities to:									Volume of EU imports of agri-food commodities from:						
Scenario	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD		OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD
FW_ret_A	0.019	0.024	0.021	0.025	0.037	0.025	0.057	0.032		-0.143	-0.173	-0.147	-0.155	-0.158	-0.201	-0.1455	-0.1597
FW_ret_R	0.016	0.019	0.016	0.020	0.029	0.020	0.045	0.025		-0.114	-0.139	-0.117	-0.124	-0.127	-0.162	-0.1165	-0.1279
FW_ret_M	0.012	0.015	0.013	0.015	0.022	0.015	0.035	0.019		-0.087	-0.105	-0.089	-0.094	-0.096	-0.122	-0.0882	-0.0967
a) Agri-food commodities include all commodities apart from retail, manufacturing and services.																

Table A7.10	FW_ret: GDP (2020) (2007 million USD, in difference from the BaU)								
Scenario	OCE	NAM	CSA	SSA	ASIA	EU27	ROE	MENA	WORLD
FW_ret_A	-0.218	-0.910	-5.302	-0.042	1.160	1613.052	3.139	1.252	1612.132
FW_ret_R	-0.174	-0.607	-4.276	0.000	1.160	1288.349	2.411	1.252	1288.115
FW_ret_M	-0.152	-0.607	-2.908	0.042	0.000	976.398	1.570	0.569	974.912
BaU value in 2020	1,456,270	19,614,155	6,213,592	1,617,046	22,711,406	20,081,207	3,819,867	41,86,211	79,699,752

A.8 FW_all scenario

Table A8.1	FW_all: GDP per capita (2020) (2007 USD, in difference from the BaU)								
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**
FW_all_A	0.270	-0.050	-0.280	0.010	0.050	-52.450	0.080	-0.020	-3.500
FW_all_R	0.200	-0.050	-0.240	0.010	0.040	-36.800	0.080	-0.010	-2.460
FW_all_M	0.150	-0.030	-0.180	0.010	0.030	-27.550	0.060	-0.010	-1.840
BaU value in 2020	35,828	52,576	9,548	1,470	5,535	39,390	12,372	7,912	10,466

Table A8.2	FW_all: Per capita consumption by EU households (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_all_A	-8.384	-0.871	-11.485	-2.022	-7.310	-11.388	-4.276	-2.310	-0.551	-4.209	-0.282	-0.512
FW_all_R	-6.711	-0.712	-9.189	-1.631	-5.857	-9.109	-3.430	-1.343	-0.377	-3.373	-0.237	-0.384
FW_all_M	-5.024	-0.534	-6.878	-1.220	-4.383	-6.816	-2.567	-0.985	-0.284	-2.524	-0.178	-0.288

Table A8.3	FW_all: Market prices for consumer goods in the EU (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
FW_all_A	-2.287	-0.573	-0.338	-0.623	-0.352	-0.365	-0.528	-3.924	-0.053	-0.683	-0.055	-0.068
FW_all_R	-1.880	-0.470	-0.275	-0.514	-0.285	-0.295	-0.435	-3.947	-0.135	-0.562	-0.038	-0.045
FW_all_M	-1.407	-0.352	-0.206	-0.386	-0.214	-0.221	-0.326	-2.987	-0.102	-0.421	-0.029	-0.034

Table A8.4	FW_all: Food security indicators (2020) (%, in difference from the BaU) a)										
Per capita food consumption by households										**Excl. EU27**	
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**		**WORLD**
FW_all_A	0.053	0.031	0.025	0.048	0.023	-8.088	0.054	0.049	-1.787		0.032
FW_all_R	0.045	0.027	0.021	0.040	0.020	-6.468	0.047	0.042	-1.428		0.027
FW_all_M	0.034	0.020	0.016	0.030	0.015	-4.841	0.035	0.031	-1.069		0.021
Market price of foods consumed by households											
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**		
FW_all_A	-0.093	-0.002	-0.121	-0.235	-0.054	-0.714	-0.182	-0.190	-0.408		
FW_all_R	-0.080	-0.003	-0.102	-0.196	-0.047	-0.592	-0.155	-0.160	-0.336		
FW_all_M	-0.060	-0.002	-0.076	-0.147	-0.035	-0.442	-0.116	-0.120	-0.252		
a) Foods consumed by households include all agri-food commodities consumed by households.											

Table A8.5	FW_all: Sectoral production in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_all_A	-3.326	-1.217	-6.455	-1.180	-2.381	-2.782	-3.187	-2.262	-7.546	0.135	0.295	-1.875	-5.080	-1.597	-7.841	-3.508	-1.659	-0.414	-3.559
FW_all_R	-2.953	-1.024	-5.175	-0.985	-1.975	-2.364	-2.707	-1.912	-6.250	0.096	0.242	-1.552	-4.523	-1.343	-6.540	-3.012	-1.864	-0.274	-3.042
FW_all_M	-2.210	-0.763	-3.864	-0.735	-1.481	-1.769	-2.026	-1.430	-4.678	0.072	0.182	-1.165	-3.385	-1.005	-4.891	-2.253	-1.383	-0.207	-2.276

Table A8.6	FW_all: Market prices for producers in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
FW_all_A	-2.045	-2.016	-2.866	-2.205	-2.375	-2.012	-1.504	-0.723	-0.346	-0.076	-0.074	-0.631	-0.412	-1.964	-0.509	-0.616	-4.250	-0.054	-0.730
FW_all_R	-1.705	-1.669	-2.361	-1.825	-1.969	-1.671	-1.246	-0.594	-0.282	-0.054	-0.049	-0.521	-0.334	-1.628	-0.414	-0.508	-4.284	-0.138	-0.602
FW_all_M	-1.279	-1.252	-1.771	-1.369	-1.477	-1.254	-0.935	-0.445	-0.211	-0.040	-0.037	-0.391	-0.251	-1.221	-0.310	-0.381	-3.245	-0.104	-0.452

Table A8.7	FW_all: Change in land demand per sector in the EU (2020) (km^2) a)								
Difference:	**Scenario**	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**ctl**	**CER**	**TOTAL**
From 2012	BaU	-2,605	-9,212	-8,046	-11,969	-13,774	-2,534	-33,073	-81,213
From 2020 (BaU)	FW_all_A	-693	-1,237	-8,249	-2,500	-9,024	-4,982	-8,285	-34,970
From 2020 (BaU)	FW_all_R	-616	-1,035	-6,593	-2,074	-7,457	-4,225	-6,939	-28,939
From 2020 (BaU)	FW_all_M	-460	-767	-4,915	-1,537	-5,579	-3,155	-5,172	-21,585

a) This table reveals incremental changes in land use. The second row reports the difference in 2020 from 2012 in the reference BaU scenario. The third, fourth and fifth row report the results occurring in the red meat scenarios (ambitious, modest and realistic versions) in 2020 in difference from the BaU scenario result in 2020.

Table A8.8	FW_all: Real wage and employment impacts in the EU (2020) (%, in difference from the BaU) a)			
Scenario	**Employment**		**Real wage**	
	Agriculture	**Non-agriculture**	**Agriculture**	**Non-agriculture**
FW_all_A	-2.978	0.047	-3.095	0.011
FW_all_R	-2.463	0.039	-2.544	0.026
FW_all_M	-1.842	0.029	-1.902	0.02

a) The labour market is segmented into agriculture (including the primary agriculture and fishing sectors) and non-agriculture (including processed foods, other manufacturing and services sectors.

Table A8.9	FW_all: EU exports and imports of agri-food commodities (2020) (%, in difference from the BaU) a)															
	Volume of EU agri-food exports of food to:								Volume of EU agri-food imports of food from:							
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**ROE**	**MENA**	**WORLD**	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**ROE**	**MENA**	**WORLD**
FW_all_A	1.554	1.490	1.594	1.660	2.010	1.723	3.062	1.926	-6.620	-8.470	-7.050	-8.660	-8.090	-6.860	-9.12	-7.67
FW_all_R	1.270	1.227	1.303	1.363	1.661	1.413	2.528	1.585	-5.520	-7.060	-5.880	-7.180	-6.720	-5.810	-7.54	-6.39
FW_all_M	0.949	0.917	0.973	1.017	1.240	1.055	1.883	1.183	-4.150	-5.310	-4.410	-5.390	-5.050	-4.360	-5.66	-4.8
	Volume of EU total exports to:								Volume of EU total imports from:							
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**ROE**	**MENA**	**WORLD**	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**ROE**	**MENA**	**WORLD**
FW_all_A	0.677	0.703	0.652	0.629	0.618	0.478	0.647	0.615	-1.356	-0.704	-1.956	-1.174	-0.601	-0.280	-0.513	-0.663
FW_all_R	0.519	0.537	0.497	0.487	0.482	0.367	0.502	0.474	-1.117	-0.560	-1.613	-0.963	-0.483	-0.229	-0.414	-0.537
FW_all_M	0.388	0.402	0.372	0.364	0.360	0.274	0.375	0.355	-0.839	-0.421	-1.211	-0.724	-0.363	-0.172	-0.311	-0.403
a) Agri-food commodities include all commodities apart from retail, manufacturing and services.																

Table A8.10	FW_all: GDP (2020) (2007 million USD, in difference from the BaU)								
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**
FW_all_A	10.903	-17.591	-181.985	15.934	222.784	-26,738.798	23.770	-12.288	-26677.270
FW_all_R	8.248	-17.894	-154.448	12.648	178.111	-18,759.537	23.658	-7.623	-18716.837
FW_all_M	6.202	-12.738	-116.135	9.236	134.018	-14,045.618	17.772	-6.144	-14013.407
BaU value in 2020	1,456,270	19,614,155	6,213,592	1,617,046	22,711,406	20,081,207	3,819,867	4,186,211	79,699,752

A.9 HD scenario

Table A9.1	HD: GDP per capita (2020) (2007 USD, in difference from the BaU)								
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**
HD	0.004	-0.159	-0.512	0.009	0.030	-18.839	0.319	0.078	-1.277
BaU value in 2020	35,828	52,576	9,548	1,470	5,535	39,390	12,372	7,912	10,466

Table A9.2	HD: Per capita consumption by EU households (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
HD	1.175	1.328	1.253	-16.860	1.275	1.119	-57.864	2.522	0.131	-33.664	0.146	0.086

Table A9.3	HD: Market prices for consumer goods in the EU (2020) (%, in difference from the BaU)											
Scenario	**v_f**	**vol**	**FBT**	**mil**	**sgr**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**	**MNF**	**SVC**
HD	-3.280	-0.886	-0.437	-1.141	-0.451	-0.535	-1.312	-2.614	-0.278	-1.456	-0.014	-0.010

Table A9.4	HD: Food security indicators (2020) (%, in difference from the BaU) a)										
Per capita food consumption by households										**Excl. EU27**	
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**		**WORLD**
HD	0.110	0.045	0.041	0.052	0.027	-8.427	0.072	0.061	-1.855		0.042
Market price of foods consumed by households											
Scenario	**OCE**	**NAM**	**CSA**	**SSA**	**ASIA**	**EU27**	**ROE**	**MENA**	**WORLD**		
HD	-0.249	-0.028	-0.233	-0.239	-0.077	-0.753	-0.220	-0.223	-0.452		
a) Foods consumed by households include all agri-food commodities consumed by households.											

Table A9.5	HD: Sectoral production in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
HD	0.01	2.84	2.88	0.39	-11.12	-17.89	-28.61	1.23	-0.40	0.15	0.29	-13.45	-0.18	-3.04	1.30	-47.95	-0.02	0.11	-29.03

Table A9.6	HD: Market prices for producers in the EU (2020) (%, in difference from the BaU)																		
Scenario	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**chk**	**ctl**	**vol**	**FBT**	**MNF**	**SVC**	**mil**	**sgr**	**CER**	**pcr**	**rmt**	**fsh**	**ret**	**wmt**
HD	-3.35	-3.36	-4.13	-3.84	-4.79	-4.42	-3.41	-1.12	-0.46	-0.03	-0.01	-1.14	-0.54	-3.61	-0.81	-1.37	-2.86	-0.28	-1.52

Table A9.7	HD: Change in land demand per sector in the EU (2020) (km^2) a)								
Difference:	**Scenario**	**c_b**	**osd**	**v_f**	**OAG**	**rmk**	**ctl**	**CER**	**TOTAL**
From 2012	BaU	-2,605	-9,212	-8,046	-11,969	-13,774	-2,534	-33,073	-81,213
From 2020 (BaU)	HD	182	4,350	4,871	3,026	-42,486	-46,703	-13,098	-89,858

a) This table reveals incremental changes in land use. The second row reports the difference in 2020 from 2012 in the reference BaU scenario. The third, fourth and fifth row report the results occurring in the red meat scenarios (ambitious, modest and realistic versions) in 2020 in difference from the BaU scenario result in 2020.

Table A9.8	HD: Real wage and employment impacts in the EU (2020) (%, in difference from the BaU) a)			
Scenario	**Employment**		**Real wage**	
	Agriculture	**Non-agriculture**	**Agriculture**	**Non-agriculture**
HD	-5.015	0.078	-4.917	0.099

a) The labour market is segmented into agriculture (including the primary agriculture and fishing sectors) and non-agriculture (including processed foods, other manufacturing and services sectors.

Table A9.9	HD: EU exports and imports of agri-food commodities (2020) (%, in difference from the BaU) a)															
	Volume of EU agri-food exports of food to:								Volume of EU agri-food imports of food from:							
Scenario	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD
HD	2.371	2.227	2.464	3.020	3.422	3.032	5.523	3.285	-19.566	-7.248	-14.088	-4.711	-6.893	-5.056	-5.189	-9.290
	Volume of EU total exports to:								Volume of EU total imports from:							
Scenario	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD	OCE	NAM	CSA	SSA	ASIA	ROE	MENA	WORLD
HD	0.422	0.457	0.376	0.529	0.444	0.406	0.558	0.456	-3.066	-0.388	-3.257	-0.829	-0.374	-0.132	-0.235	-0.563
a) Agri-food commodities include all commodities apart from retail, manufacturing and services.																

Table A9.10	HD: GDP (2020) (2007 million USD, in difference from the BaU)								
Scenario	OCE	NAM	CSA	SSA	ASIA	EU27	ROE	MENA	WORLD
HD	0.152	-59.444	-333.354	10.068	121.255	-9604.412	98.613	41.528	-9725.594
BaU value in 2020	1,456,270	19,614,155	6,213,592	1,617,046	22,711,406	20,081,207	3,819,867	4,186,211	79,699,752

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