Federal Ministry
of Food, Agriculture and
Consumer Protection

Report on active climate protection in the agriculture, forestry and food industries and on adaptation of agriculture and forestry to climate change

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Contents

1. Introduction

Climate protection is among the most important environmental, social and economic policy challenges of modern times. This applies globally and regionally to all sectors of our societies. It also confronts the agriculture and food industry with the question of how the greenhouse gas emissions (GHG emissions) it produces can be kept as low as possible and what steps and measures are necessary for adaptation to the changed framework conditions.

Since time immemorial, it has been necessary to operate in accordance with the location. What is new, however, is the speed with which it will be necessary to adapt to climate change.

In future to feed 9 billion people adequately and in an as balanced way as possible is a mammoth task. The fight against hunger and malnutrition on the global level continues to be one of the most important tasks of the international community of states. Over 850 million people worldwide are still hungry and more than 2 billion are suffering from malnutrition.

Global population growth of approximately 80 million per year combined with higher incomes in states with strong economic growth lead to a great increase in quantitative demand for foods and feeds. The FAO estimates a global annual rise in demand for agricultural products by 1.6% until 2015 and then by 1.4% by the year 2030. Worldwide demand for meat will double by 2050. In addition, there is the task of supplying billions of people with energy just for cooking. Today, most people around the world cook with wood or other biomass.

Therefore in the foreseeable future the agricultural industry will be required to attain qualitatively and quantitatively high yields. At the same time, we know that with increasing production, the emissions of the greenhouse gases methane and nitrous oxide, which always originate from agricultural production due to natural processes, also increase. This is a trade-off that can only be mitigated to a very limited extent.

The primary task of agriculture is to supply foods in adequate amounts and quality. They must be produced sustainably with the lowest possible emissions. International negotiations should ensure that this pathway is taken worldwide and avoid that the emissions reduced in Europe are additionally then emitted in other countries for production of foods for the European market. It would make no sense from a climate policy perspective to reduce production in Germany only for it to be increased in other countries.

The greenhouse gas emissions caused by humans must be distinctly reduced. This will have consequences for lifestyles, for the alignment of new technologies and for forms of management, also in the food supply chain. More than ever, we need to handle our limited resources sustainably. Conservation in particular has a direct effect.

We must focus our attentions on measures with major effects and low costs and avoid actionist behaviour. The reliability of political decisions and therefore planning reliability must be given the greatest weight.

Climate change sets forestry before special challenges. Compared with agriculture, due to the long-term nature of production, decisions must take periods of many decades to a few centuries into consideration. Within these periods of time, climate change will have had a more major impact than in agriculture, which can make new decisions and react anew each year or every few years. Due to the nature of things, uncertainties in foreseeing such long periods of time will always be great. This must be taken into consideration when making political and operative decisions.

We must already initiate steps to convert the forests to climate-change tolerant populations and intensify research on the impacts of climate change. Due to the complex ownership structures and difficult accessibility of forest owners, it is particularly important that they be informed as soon as possible. For the question of extending product cycles or cascade use of forest biomass, a way must be found together with the timber and power industries to altogether optimize carbon fixation. Agricultural policy and climate protection policy are very strongly determined by international conditions. The forthcoming negotiations for a successor convention on climate protection for after 2012 will necessitate decisions that equally do justice to the demands made on the agriculture, forestry and fishing sectors with regard to food and raw materials production as well as climate protection.

Regardless of the fact that climate change is a global challenge, this report refers to Germany.

2 Climate change

Climate change is characterized mainly by higher temperatures[1], whereby the greatest increases are observed in higher latitudes and altitudes. These are accompanied by seasonally and regionally changed distributions of temperatures and precipitation. In addition, the atmosphere contains higher levels of CO_2[2] and the sea level is rising[3]. For agriculture and forestry, the increase in extreme events, such as hot spells and dry seasons, storms, torrential rains and hail are of particular significance.

Projections are used to describe future developments, which primarily are influenced by the emission scenarios on which they are based[4]. While there are a large number of prognoses for the year 2100 for future global trends, the short and medium-term and regional predictions are very sketchy. For Germany it is of particular importance that slight increases in median annual precipitation are expected for western and southern Germany and slight decreases for Brandenburg, Mecklenburg-Vorpommern and Saxony with increasing precipitation in all federal *Länder* during the winter months. On the other hand, higher temperatures for all of Germany are very probable.

3 Mitigation

3.1 GHG emissions and CO_2 commitments by the agriculture and food industry

Along the value chain for foods and renewable resources in Germany, approximately 200 Mt CO_{2eq} are emitted (Table 1).

The production and provision of inputs for German agriculture generate GHG emissions of approximately 45 Mt CO_{2eq}, with fertilizers and feeds the chief single positions. This also includes emissions through inputs such as nitrogen mineral fertilizers and high-protein feed imported from other countries.

In the year 2005 agriculture and agricultural land use generated GHG emissions of approx. 111 Mt CO_{2eq} with approx. 42 Mt CO_{2eq} from ameliorated moorland and from moorland used as cropland or grassland, approx. 37 Mt CO_{2eq} nitrous oxide emissions from fertilization of

1 Increase in the median global ground level temperature from 1906 to 2005 by 0.74 °C.
2 Increase in the global CO_2 concentration in the atmosphere from 280 ppm to over 380 ppm.
3 Rise in the median global sea level in the 20th century of about 17 cm.
4 Report by the Federal Government (cabinet decision dated 19.11.2008). German Adaptation Strategy to Climate Change

agricultural soils and from agricultural nitrogen surpluses and approx. 18 Mt CO_{2eq} methane emissions from animal digestion being the chief single headings.

The food industry emits approx. 11 Mt CO_{2eq} from direct energy consumption, in addition to indirect emissions from electricity consumption and capital goods. Transport and trade take up approx. 35 Mt CO_{2eq}. According to estimates, private households and the hotel and restaurant industry release approx. 75 Mt CO_{2eq} during food procurement, preparation and heating of kitchens and dining rooms.

Forestry, with approx. 79 Mt CO_{2eq} (in 2006), is a significant carbon sink. Only approx. 6% of this carbon capture is generated by the creation of new forest areas through afforestation. On the other hand the increase in carbon in the existing forests due to a rise in the timber stocks is the by far more important factor. Yet, even harvested timber and timber used in construction store additional larger amounts of carbon over a long period of time. Presently however a large portion of the sink growth cannot be used to offset the objectives of the Kyoto Protocol.

The use of renewable energies from biogenic sources contributes to substitution of fossil energy sources. In the year 2006 biomass from agriculture for biogas and biofuels contributed to a reduction of GHG emissions by approx. 18 Mt CO_{2eq} (Table 2). The use of solid fuels, chiefly timber, contributed an additional 23.2 Mt CO_{2eq} and wastes (sewage and landfill gasses, burning of biogenic wastes) an additional 6.5 Mt CO_{2eq}.

Substitution of resources with renewable resources also contributes to mitigation of GHG emissions, since these can be produced, transported and processed using comparatively little energy. For product-related GHG balances, complete product-related life-cycle analyses are required for the emission of GHG, biological assessment of CO_2 or substitution of fossil resources.

Table 1: **GHG emissions in the German agriculture and food industry**

		CO_2	CH_4	N_2O	Total
		in CO_2 equivalents			
Inputs for agriculture	estimated (1999)				**45.3**
Electricity		3			3
Fertilizer		8.4		7.9	16.3
Feed		.	.	.	13
Machinery, buildings, other inputs		13			13
Agriculture	CRF category (2005)				**111.6**
Direct energy consumption (agriculture, forestry and fishing)	1.A4c	6.4	0.03	0.03	6.5
Enteric fermentation	4.A		18.3		18.3
Manure management	4.B		5.0	3.0	8.0
Agricultural soils	4.D		-0.6	37.8	37.2
Land use /land use change: cropland	5.B	25.0			25.0
Land use /land use change: grassland	5.C	16.6			16.6
of which emissions from moor use	*4.D, 5.B, 5.C*	*36.9*		*5.1*	*42.0*
Production of foods and feeds, beverages (EEA, 2005)					**10.7**
Trade	Kramer et al. (1994)				**35.0**
Packaging		13.4			13.4
Goods transports		10.1			10.1
Buildings management/storage		11.5			11.5
Households	Kramer et al. (1994)				**75.0**
Forests	CRF category (2005)				**-78.7**
Land use/land use change					
Remaining forest area	5.A	-74.1			-74.1
New forest areas	5.A	-4.7			-4.7

Sources: *National Inventory Reports 2006 and 2008* (by Common Reporting Framework categories (CRF)); Destatis (2007): *Economy and Use of Environmental Resources.* Tables on Environmental-Economic Accounting 2007. Part 6: Greenhouse gases (total, CO2, CH4, N2O), Table 6.1.2: Direct domestic emissions of greenhouse gases; Kramer, I., Müller-Reißmann, K.F., Schaffner, J., Bossel, H., Meier-Ploeger, A., Vogtmann, H. (1994): *Landwirtschaft und Ernährung. Veränderungstendenzen im Ernährungssystem und ihre klimatische Relevanz*. Enquête-Kommission Schutz der Erdatmosphäre des Deutschen Bundestages: Landwirtschaft und Ernährung. Teil B; Inputs estimated as part of the project on the EEA reporting module Agriculture and Environment at the Research Institute for Rural Areas, Forestry and Fisheries of the Johann Heinrich von Thünen-Institut (vTI).

Table 2: CO_2 avoidance via the use of renewable energies from biogenic resources in Germany in the year 2006

	Agricultural raw materials	Timber	Waste
	Mt CO_2		
Electricity			
Biogenic solid fuels		5.8	
Biogenic liquid fuels	1.0		
Biogas	3.1		
Sewage gas			1.0
Landfill gas			1.1
Biogenic share of waste			3.2
Heat			
Biogenic solid fuels (household)		14.3	
Biogenic solid fuels (industry)		2.6	
Biogenic solid fuels (cogeneration plants/heating plants)		0.5	
Biogenic liquid fuels	0.3		
Biogenic gaseous fuels	0.7		?
Biogenic share of waste			1.1
Biofuels			
Biodiesel	10.4		
Vegetable oil	2.0		
Bioethanol	0.5		
Total	**18.0**	**23.2**	**6.5**

Source: BMU (2007) Renewable energy sources in figures - national and international development. Version: November 2007, Internet update. p. 19: Total CO2 avoidance via the use of renewable energy sources in Germany, 2006.

3.2 Mitigation options for the agriculture and food industry and the consumers of foods

3.2.1 Upstream sectors (input products incl. feed, energy)

The agricultural sector can contribute to a decrease in indirect GHG emissions from the upstream chain through more efficient use of inputs. The chief fields of action here are nitrogen fertilization and livestock feeding. Other roles are played by the demand for electric power, the utilization of machinery and building use. A precise quantification of indirect GHG emissions from inputs is presently only possible by approximation due to methodical questions and lack of data.

Imports are not included in the German GHG balance, so that conservation of fertilizers and feeds only has an indirect impact on the German GHG balance in consideration of the high share of imports. A dropping demand for inputs can lead to price adaptations, which may lead to a rise in the use of inputs in other places. With reference to the respective agricultural products produced in Germany, this may improve the GHG balance, however from a global perspective the market-based system correlations lead to lower net relief. If, because of saved inputs, production in upstream sectors is reduced and if the affected enterprises are part of the GHG emissions trading system, these savings generate degrees of freedom for increasing GHG emissions in other enterprises. Nevertheless, the correlations cited by no means speak against efficiency-oriented further development of agricultural production systems. Because of such indirect effects, however, the assessment of gross relief is connected to imponderables.

3.2.2 Agricultural production (agriculture, forestry and fishing)

Emissions from agriculture are primarily system inherent, so that emission reductions are usually connected with production cuts. For instance, the emission reductions in agriculture in the early 1990s were chiefly the result of the decrease in livestock resulting from the structural change after German reunification. Systematic and quantitative statements on how many GHG emissions from agriculture can be reduced using which measures in Germany at what costs are not yet available. Information is available on the level of the agricultural holdings for individual measures. The costs of CO_2 avoidance vary considerably depending on the operative prerequisites. They are decisively determined by the extent to which the potentials for GHG reduction were already previously utilized, for example through optimized feeding, needs-adjusted fertilization or energy-efficient stables. Further emission reductions can frequently only be achieved by means of disproportionately high costs. In most cases, the CO_2 avoidance costs are distinctly higher than the market value for emission allowances of presently approx. 27 €/t CO_2.

Adherence to good agricultural practice, which includes efficient use of input products, usually results in the comparatively lowest emissions. It must be taken into consideration that minimization of GHG emissions from a economic perspective has not previously been among the business objectives.

Agriculture can also contribute decisively to mitigation of GHG emissions by aligning land use to the protection of soil organic carbon. Corresponding measures by agriculture are frequently connected with use restrictions, in particular relinquishing grassland ploughing or the re-imbibition of moorland, and lower yields at higher costs.

Forestry influences the sink capacity of the forests through afforestation, through the form of forest management, through the extent of timber removal and through the marketed product range (product cycles). Increased timber use amplifies the effects of these impacts (long-term storage of carbon in timber products; substitution of comparatively more energy intense and fossil resources; cf. Chapter 3.2.3).

<u>Overview of farm-level measures for minimizing GHG emissions</u> (not final)

- **Fertilization**
  - Demand assessment
  - Ground-level application of liquid livestock manure
  - Immediate incorporation of liquid livestock manure
  - Application at the suitable time in accordance with the Fertilizer Application Ordinance
  - Observance of minimum distances from surface bodies of water
  - Use of low spray drift machinery for liquid fertilizers
  - Use of precision casters for solid fertilizers
  - Row fertilization for row crops
  - CULTAN method or depot fertilizers
- **Soil tillage**
  - Conservational soil tillage
  - Direct sowing
  - Cultivation of perennial crops (in particular for renewable resources)
  - Cultivation of inter-row crops
- **Protection of the carbon stocks in soils**
  - Avoidance of grassland ploughing
  - Re-imbibition of drained organic soils
  - Management forms that conserve and build up humus
- **Livestock husbandry**
  - Fewer ruminants
  - Increasing lifetime performance per animal
  - Feeding (rations rich in high-energy feeds; use of feeding fats or fatty acids; feed additives with methane-reducing potential; use of hydrogen bonding substances with energy supply potential for ruminants)
  - Improved animal health
  - Prolonged useful life of cows
  - Reduction in raising duration and number of young cattle to be raised
  - Adequate storage capacities for livestock manure
- **Sinks by forestry**
  - Forest management, in particular timber use, growth acceleration
  - Afforestation

- **Buildings and building installations**
  - Measures for the improvement of energy efficiency

3.2.2.1 Land use (agricultural plant production and forestry)

– ***Nitrous oxide emissions from fertilization***

Increasing the utilization of nitrogen fertilizers (fertilized nitrogen turnover in crop) to avoid unproductive surpluses contributes to decreasing the adherent direct and indirect N_2O emissions, as far as possible maintaining high productivity (thus no extensification). The observed variations in the administration of mineral nitrogen fertilizer per hectare in agricultural holdings of similar structures reveals that very different nitrogen utilization rates occur from farm to farm. This means that corresponding potential improvements, in particular with regard to the utilization of livestock manures, can be expected. To lower nitrogen balance surpluses there are a number of single technical measures available, which can be economical depending on the operative conditions. Reduction of nitrogen mineral fertilizers also contributes to lowering the nitrogen run-off in waters and gaseous NH_3 losses. Not taking GHG emissions from the upstream chain into account and assuming that nitrogen surpluses will be reduced (thereby avoiding direct and indirect N_2O emissions and cost savings for nitrogen mineral fertilizers), the avoidance costs of 1 € per kg nitrogen correspond to a cost effectiveness of approx. 30 € t CO_{2eq}. However, such low costs per kg of reduced nitrogen surplus are hardly attainable. Yet, also taking water protection objectives into consideration, measures for increasing nitrogen efficiency are more favourable.

Forest management

In recent decades, a considerable amount of CO_2 was fixated in biomass in German forests (75 Mt CO_2 annually). The form of forest management and the extent or structure of timber removal determines the amount of CO_2 fixation.

The timber stocks in Germany are large by historical and regional comparison. This increases the risk of uncontrolled reduction of stocks (e.g. through natural disasters such as wind throw, insect calamities). Moreover, the potentials for further CO_2 fixation in biomass are limited. Timber harvesting removes biomass from the forest and temporarily lessens the timber stock. Through silvicultural controls, timber use can contribute to increment-strong, robust forest with rich timber reserves and to securing and improving their CO_2 sink function. A high degree of conservation of growing stock also increases the risks for conservation of growing stock and in most cases is accompanied by rather low increments. Management without clear cutting also avoids humus decomposition and the release of CO_2 and N_2O.

The increase in the timber increment can be brought about, for instance, by changing tree species favouring faster growing tree species (e.g. Douglas fir or red oak) or origins, by taking advantage of strong-growth age periods by means of lowering the rotation period, by controlling thinning or by fertilization for growth acceleration. However, lowering the rotation period leads to a reduction in carbon stocks in the medium standing biomass and thereby to a carbon source. Therefore this measure is contrary to preservation of carbon stocks in the forest.

3.2.2.2 Changes in land use

Changing land use or preserving existing land use ratios is decisively determined by the availability of appealing use alternatives to individual farms and their opportunity costs. In turn, the opportunity costs are greatly dependent on subsidies from the first and second pillars of the Common Agricultural Policy.

Restrictions to production by segments of agriculture can, through outsourcing, lead to intensification and land use changes in other locations, even outside of Germany.

– ***Protecting permanent pasture land from ploughing and conversion to cropland***

Ploughing permanent pastureland areas results in a part of the soil organic carbon stocks being decomposed as CO_2, in particular on conversion to cropland. This also releases nitrogen, some of which escapes as N_2O. According to the NIR, emissions from grassland ploughing in the year 2004 were almost 1 Mt CO_{2eq}. Protection of grassland areas from ploughing and conversion to cropland avoids these CO_2 and N_2O emissions, with positive effects for water protection (nitrate leaching) and nature conservation (grassland as habitat). The amounts of CO_2 and N_2O released are highly location specific. Old swards, humus and boggy locations have greater soil organic carbon stocks than young grassland on mineral soil. On fen soils the difference in the GHG release between cropland and grassland use can be particularly great due to the greater groundwater depletion under cropland.

The current relative economical advantages of forage cropping over grassland use leads to rising opportunity costs of grassland preservation. Against this background there is a risk that short-term grassland preservation would only mean a delay of the release of SOC and nitrogen. While this would prevent temporary GHG release, the annually accrued opportunity costs of alternative uses would amass to very high long-term costs if no alternative uses are found for the grass, e.g. for bioenergy. The cost effectiveness is therefore very dependent on the length of the period under consideration.

Against this background, agriculture needs alternative use options for present grassland areas. These could include grassland use for the production of biogas substrates, establishment of short-rotation plantations or extensive pasture on areas valuable for nature conservation.

– ***Conversion of cropland to permanent pastureland***

Conversely, the establishment of permanent pastureland on prior cropland has a longer-term effect of a certain accumulation of soil organic carbon, because a perennial sward retains a humus level that is not decomposed. Due to the low economic appeal and low acceptance of the establishment of new permanent pastureland, hardly any area potential is anticipated.

– ***Renaturation and imbibition of fens***

With more than 40 Mt $CO_{2eq,}$ emissions from agriculturally used moors, these make up over one third of all direct emissions from agriculture. Ameliorated locations release CO_2 and N_2O of up to 15 t CO_{2eq} per hectare and year. In particular, larger, drained bodies of peat have high emissions over many years. Raising the groundwater table lowers the decomposition of peat and intense imbibition can even reinitiate carbon accumulation. However, imbibition also leads to a rise in CH_4 emissions.

Imbibition of fens results in the abandonment of crop use and more intensified grassland use. Depending on the existing use intensity and profitability, a change in use can be expensive and problematical to various degrees. In larger lowlands a very large number of property owners and managers and even towns and infrastructures can be affected, which greatly impedes implementability or even entirely prevents it. If areas are bought up by the public authorities, the costs can be very high; however, taking the objectives of water and nature conservation into account, if the contributions to individual objectives are allowed for, especially over a longer given period of over 10 years, this can result in more favourable cost effectiveness of CO_{2eq} avoidance. Use of the biomass growth of imbibed areas can tend to improve cost effectiveness.

– ***Afforestation***

Afforestation of previous cropland and grassland areas leads to an accumulation of carbon in the timber growth and in the soil. This is done chiefly on locations that are unfavourable for agricultural use. This has chiefly positive effects for water protection; however, during establishment soil tillage can cause substance outputs and erosion. In the year 2005 approximately 5 Mt CO_2 was fixated by afforestation measures. The CO_2 avoidance costs from afforestation are approx. 50 €/t (not allowing for subsidies). In the light of trends in the agricultural sector, however, there are only few agricultural areas in Germany available for afforestation.

3.2.2.3 Livestock husbandry

– ***CH_4 emissions from ruminant digestion***

Emissions from the digestive tracts of cattle and sheep are approx. 17 Mt CO_{2eq}. Modified compositions of feed rations and the use of feed additives could further reduce the CH_4 emissions from the digestive tracts of cattle and sheep to varying extents. Possibilities are increased amounts of high-energy feeds, fats and the additives ionophores (presently prohibited in the EU), halogen derivates, propionic acid pre-stages (organic acids), secondary vegetable ingredients and yeasts. In addition, work is underway on methods of immunization against specific rumen microbes. The effectiveness and controllability of these options are, however, limited. Therefore measures with direct effects on digestion-related emissions are presently not available or rejected on animal protection grounds.

In contrast, increasing animal performance, efficient feed conversion and lengthening lifespan and useful life contribute to reducing product-related GHG emissions. One example of the effects of increased animal performance is milk production. By raising individual animal performance, direct emissions from dairy cattle farming and the progeny breeding of heifers (CH_4 from digestion and livestock manure storage, N_2O from livestock manure storage and application, not taking feed production into consideration) have been lowered by approx. 1 Mt CO_{2eq} since 1992 (or after extensive completion of the livestock population cutbacks in the new *Länder*). The GHG emissions per kilogram of milk dropped by approx. 7%. Biological and technical progress will continue to contribute to gradual improvements. Another option is the restructuring of cattle herds, whereby suckler cows can be replaced as “landscapers” by progeny breeding heifers in the dairy herds. Progeny breeding for beef farming could be produced with the aid of crossbreeding with the dairy herds and with once-bred heifers.

– ***CH_4 and N_2O emissions from livestock manure storage***

Approx. 8 Mt CO_{2eq} (5 Mt CH_4 and 3 Mt N_2O) originate from livestock manure management (storage). Gas-tight storage of manure, preferably via co-fermentation in biogas plants, reduces CH_4 and N_2O emissions from manure storage. This also prevents gaseous NH_3 losses from storage. N_2O emissions are probably in part only shifted to the time following application, and during application increased NH_3 emissions can occur. An increasing, but not statistically recorded share of the emissions has already been avoided in recent years by means of co-fermentation in biogas plants followed by gas-tight storage. The cost effectiveness of biogas plants for GHG avoidance rises along with higher percentages of livestock manure. Against this background, an increase in the percentage of livestock manure in existing plants would be particularly favourable.

3.2.2.4 Direct emissions from energy input

The agricultural sector emits approx. 6.5 Mt CO_{2eq} directly from the use of fossil energy sources. Most of the energy is consumed for heated greenhouses and stables (especially for pigs and poultry), rotating soil tillage and transports. Conservation of fossil energy sources in the agricultural sector are enabled by more efficient technologies, energy-saving methods (e.g. reduced soil tillage, outdoor climate stables) and substitution by renewable energies. In energy-intensive horticulture in particular, which consumes about 1/3 of the agricultural heating energy, there is considerable potential for increasing energy efficiency.

3.2.3 Use of renewable resources

Renewable resources can contribute, for one, to long-term fixation of carbon (e.g. construction timber, durable timber products), and secondly to material recycling and energy production for materials produced with high energy input (aluminium, glass, plastic, etc.) or replace fossil energy sources. In addition timber and other renewable resources have good thermal insulation properties, which facilitate heat energy conservation. Cascade use of renewable resources through (repeated) material recycling and ensuing energy production is another option that enables multiple substitutions.

The significance of the production of renewable resources has distinctly increased in agriculture. For example, in the year 2007 in Germany approx. 2 million hectares were utilized for the agricultural production of renewable resources (273,600 hectares of industrial crops for material use, 1,771,000 hectares of energy crops).

Biomass plays a crucial role in the production of regenerative energies. Of the 224,204 GWh of end-point energy produced in the year 2007 from regenerative sources, 9,980 GWh were provided for electric power (11.4% of regenerative electric power production), 79,289 GWh for heat (87.9% of regenerative heat production) and 46,556 GWh for fuels (100% of regenerative fuel production). Therefore, the percentage of biogenic energy sources in regenerative energy production is 60.6% (related to end-point energy). The use of biogenic energy sources avoided GHG emissions of 47.7 Mt CO_{2eq}.

There are a great number of options available for energy use from biomass from agriculture and forestry. The objective is substitution of fossil energy sources. The carbon fixated during plant growth is released upon combustion with neutral emissions. Nevertheless, we must also additionally take the direct and indirect GHG emissions arising from biomass production into consideration. Competition with food and feed production for the usage of productive agricultural areas may cause crowding-out effects, which could result in intensification and area use changes in other places.

At present biofuels, primarily biodiesel, and biogas are of great significance. However, the CO_2 avoidance costs for biofuels are especially high.

The production of solid fuels on less productive areas exhibits high yields of energy per hectare, thus lowering undesired side effects such as intensification and area use changes. Timber production for energy from biomass offers synergies with objectives of water, nature and landscape conservation. The use of residual and waste substances, which includes biomass from landscape management with approx. 2.2 Mt p.a., offers considerable potentials. Also, cascade use of agricultural products and increased use of manure in biogas plants, especially in existing plants, can contribute to improving the cost effectiveness of climate protection through biomass.

3.2.4 Fishing industry

The fishing industry is the only industrialized food production sector that is based to a considerable extent on natural wild populations. GHG emissions arise in this respect only from the use of input products or their production (upstream sectors). The energy requirements of sea fishing are significant. Approximately 60% of the fuel employed is used for propulsion of the fishing industry vehicles, while about 35% are needed for the catch and refrigeration. The remaining energy is needed for illumination, navigation, etc. Using the cod as an example, the energy expended for one kilogram of frozen filet from the Baltic Sea totals approximately 90 MJ/kg, of which the fishery alone consumes 72%, while the fish industry requires only approximately 1.8 MJ/kg. Similar to the energy requirement, the bulk of CO_2 emissions in the sector of the food fish are caused by the fishing industry. Use of industrial fish to feed fish in aquaculture, the CO_2 emissions per kilogram of fish is comparable with the emissions caused by sea fishing. If we employ the example of the Baltic cod, approximately 12 kg CO_2 equivalents per kilogram of fish filet are caused by the consumption of (previously frozen) filets. Approximately 90% of the total product-related CO_2 equivalent pollution is allotted to the fishing industry activity. If we leave out the fishery sector (incl. energy used by it for refrigeration), approximately 1.2 kg CO_2 pro kilogram of cod filet is released, the by far largest portion of this amount (ca. 95% corresponds to approximately 1.1 kg) is from transports. Of this, the transport by customers from the retail shop to their households causes the largest share of CO_2 emissions from transport. By contrast to cod fishing, the catch by the Danish plaice fisheries is responsible for only approximately 50% of the CO_2 emissions. 10% of the CO_2 consumption is allotted to the trade (primarily transport) and processing and approximately 30% to the consumers.

Predominantly, the chief contributors to pollution in the fishing industry are sea fishing and aquaculture production (on animal more than on vegetable feed basis). The fish processing industry only makes a small contribution to the pollution. There are potentials for conservation therefore primarily through increasing the energy efficiency of catching methods (e.g. increased use of passive catching equipment), but also through improving the accessibility of the resources, e.g. by targeted regeneration of offshore populations.

3.2.5 Food processing

The food processing industry, with a share of 5-10% of the total product-related GHG emissions, contributes a comparatively minor extent to GHG emissions in the sector of food production/nutrition. Direct gaseous emissions are released only by a few manufacturing processes and, compared to the extent of indirect emissions, are rather minor. CO_2 recovery processes[5] are therefore hardly purposeful. Indirect emissions result primarily from process-dependent energy consumption, whereby thermal treating (heating, cooling) and intensive mechanical interventions (milling, pressing) bear considerable share. In the food processing industry, GHG emissions can be reduced chiefly through energy-efficient production, storage and logistics and by minimizing or optimizing packaging materials. The manifold, individual approaches towards the sustainable use of established manufacturing processes to save energy and reduce climate-relevant gasses have been pursued for many years, not least for reasons of economy. In addition, modified or innovative production processes are being developed for energy conservation purposes. Utilization of heat-power cogeneration is an efficient supply form in the production of energy, also in conjunction with biogas plants. Certification of production enterprises enables them to identify possibilities for energy conservation or reduction of GHG. In March 2008 the number of EMAS-certified businesses and organizations in the food industry in Germany was cited at 103. In addition to most efficient possible use of agricultural raw materials, which avoids processing residues, handling of unavoidable residues is important. Targeted reconditioning of valuable residues from conventional processing does require an additional input of energy, yet it enables additional value creation and avoids the mere release of GHG from composting or landfill disposal. In addition, processing residues and food residues from food production can also be used to produce energy. Last but not least, food production must reduce the consumption of drinking water and drinking water processing must be optimized.

Parts of the food industry (approx. 100 plants during the first trade period 2005 – 2007) are subject to the Greenhouse Gas Emission Trading Act (*Treibhausgasemissionshandelsgesetz* - TEHG). In addition to lessening emissions in the plants, they can also employ the Kyoto mechanisms (certificate trading, project mechanisms).

3.2.6 Trade and transport of foods

The trade accounts for little of GHG emissions in the food sector (5-10%). Nonetheless, even here there are potentials for reduction (approx. 5%). In raw materials acquisition regional overlaps of different production sites should be avoided. The vehicles used for transport to the

[5] CO_2 recovery processes are processes such as those used for beer production. CO_2 is a by-product of alcoholic fermentation and is also a necessary additive in beer production. Therefore, increasing numbers of breweries capture and recover it. To avoid contamination, CO_2 runs through various process stages within the CO_2 recovery plant. Different types of impurities are removed by washing, condensing, drying, purifying and liquefying.

processing plant should be optimally employed and used to capacity. The trend towards larger production facilities appears wise until the dropping energy requirement per unit of food processed is compensated by the increased energy requirement for raw materials delivery. Similar considerations should be made in the distribution of the finished products, whereby the transport routes here are far more complex. They travel not only to the trade, but also to the further processing food industry, to bulk consumers or production partners. Imports and exports additionally complicate the diagram. It is nevertheless necessary to examine energy consumption by raw materials acquisition, product processing and distribution for increased intra-regionality or internationality on the one hand and increased regionality on the other hand. For example, foods imported by air from overseas are a great burden to the climate. The CO_2 emissions from air transports are assessed as 177 times higher than sea transports.

3.2.7 Consumption of foods

With a share of approximately 16-20% the food category makes a major contribution to Germany’s GHG emissions. Of these, 55% occur during manufacture and distribution (production, processing and goods transports) and 45% occur through energy consumption for storage, preparation and consumption of foods in private households and in away-from-home consumption. Private shopping excursions bear a relatively high percentage of approx. 5%.

One very crucial factor is the amount of animal products in nutrition. The by far largest percentage of emissions occurs during the production and processing of dairy products (53% with average consumption of 287 kg/household/year) and meat, in particular beef (25% with average consumption of 106 kg/household/year). Approximately 10% of GHG emissions are allotted to vegetables, which at 31% (average 317 kg/household/year) makes up the largest percentage of food consumption. In this respect the greatest conservation potential lies in the composition of the menu. It is estimated that a meat-reduced diet could save up to 27% over a mixed diet, and another 15% (i.e. a total of up to 42%) of GHG emissions could be prevented with a vegetarian diet.

Further emissions could be avoided through consumption of seasonal outdoor-grown products (up to 5%), of regional products (approx. 5%), by changing eating habits with organic products (approx. 6%) and by not using frozen products (approx. 2%). Moreover, energy-saving household appliances and the choice of climate-friendly means of transport for shopping can contribute considerably to reducing CO_2 emissions. The figures are always based on estimates and depend upon manifold factors so there is a great margin of fluctuation.

From these, the following recommendations for climate-friendly nutrition have been derived for consumers:

- More vegetable and less animal foods

- No products imported by air, as many regional foods as possible
- Seasonal vegetables and fruit grown outdoors
- Fresh, little-processed foods instead of frozen goods
- Energy efficient household appliances
- Shop on foot, by bike or with public, climate-friendly transport
- Avoid letting foods spoil

These recommended modifications in consumer behaviour largely involve no extra costs and even lower costs. A comparison of food costs for various diets shows 12% lower food costs for a whole food diet than for a mixed food diet.

The recommendations for a climate-friendly diet are exactly the same as those for a healthy diet. Implementation not only prevents negative consequences to health, but also prevents high food-related health costs. In this case, therefore, there is high goal congruence: a healthy diet is not only good for humans, but also for the environment and the climate.

3.3 Federal government measures

In view of the problems[6] in ascertaining the total CO_{2eq} emissions of single agricultural holdings, it will not be possible in the foreseeable future to involve single farms (somewhat analogously to energy-intensive large firms in industry) as actors in the EU emissions trading system. The political challenge is therefore to design measures or a suitable combination of measures that are administrable, that in total lead to efficient adaptation of agriculture and the food sector for climate protection and do not run contrary to the objective of ensuring the supply of foods, renewable resources and environmental assets. Research is needed to develop efficient, sustainably effective funding measures.

The choice of climate protection measures in the agriculture and food sector should be aligned to the CO_2 avoidance costs taking multifunctional effects into consideration. There is a need for research in many cases. We can, however, already cite important fields of action based on available knowledge.

– ***Protecting permanent pasture land from ploughing and conversion to cropland***

At present grassland ploughing is being carried out to an increased extent in many federal *Länder*. One reason for this is the high economical benefits of agronomic use; another is that the last agricultural reform made it possible to use former grassland areas as cropland without

6 Large number of, in part, very different sources and sinks, chronological and spatial delineation, control

exclusion from direct payments. Until 2005 areas used as grassland before 31.12.1991 were excluded from direct payment for field crops. The drop in permanent pasturelands eligible for aid should be countered by *Land* ordinances in the affected federal *Länder* with duties to obtain permits for permanent pastureland ploughing applying the valid cross-compliance provision. In addition, better enforcement of existing restrictions to grassland ploughing in nature conservation and water protection laws can contribute to the protection of grassland. In the long term, however, it will be necessary to improve the economic benefits of grassland compared to forage cropping. If this problem is not solved, solutions must be sought using funding programmes or other regulatory instruments.

– ***Renaturation and imbibition of fens***

A first step towards protection of the moors is more consistent grassland conservation on humus-rich soils and moor sites. Imbibition of fens and their use to provide solid fuels is an advisable option for supplementing renewable energies from biomass. Some federal *Länder* have moorland conservation programmes for renaturation, which are implemented as part of projects or regional redevelopment, as compensation scheme and replacement measures under nature conservation law, in public forests or in the scope of forest funding. Expansion of such programmes in consideration of multifunctional effects (water, forest and nature conservation, biomass production) should be examined.

– ***Afforestation***

Afforestation is an eligibility criteria for support in the majority of the federal *Länder*, its contribution to climate protection will not, however, go far beyond the extent already achieved due to low economic appeal, low area potentials and limited funding budgets. Initial afforestation is also an option as compensation schemes and replacement measures under nature conservation law. Establishment of new forests can be supported by planning laws that identify afforestation area in landscape or land use planning.

– ***Measures in agricultural production***

CH_4 and N_2O emissions are closely tied to production activity. There are very large differences between individual holdings. Use of good farming practice brings about emission reductions. Targeted research and consulting can further develop the biological and technical progress and be provided to producers.

– ***Reducing methane emissions from livestock manure storage***

CH_4 emissions from livestock manure storage should be reduced by means of increased co-fermentation in biogas plants and storage in gas-tight fermentation residue depots, especially also by increasing the amount of livestock manure in existing plants. Contributions can be made with incentives or penalties for the use of livestock manure as a co-fermenter in biogas plants and funding and/or penalties for gas-tight storage of fermentation residues. New biogas plants should by all means have sufficient and gas-tight fermentation residue depots. Use of livestock manure in biogas plants should be statistically recorded to document the climate protection impacts achieved.

– ***Reducing nitrous oxide emissions from fertilization***

Under the sustainability strategy of the Federal government, the existing agricultural nitrogen surplus according to the total balance (sector farm balance) must be reduced by 20 kg/ha to 80 kg/ha by the year 2010. This reduction would accompany a reduction in nitrous oxide emissions by approx. 3 Mt CO_{2eq} per year. Under the Fertilizer Application Ordinance the individual operating balance surpluses must be lowered by the year 2011 to 60 kg/ha (different basis of calculation). Therefore the Fertilizer Application Ordinance already makes a considerable contribution to lowering nitrogen balance surpluses in agriculture.

Measures to increase nitrogen utilization in agriculture help reduce N_2O emissions from agriculture. In concrete terms, measures should be developed and implemented towards more nitrogen-reduced feeding and increasing the utilization of nitrogen fertilizers in agriculture. In addition, more nutrient-efficient crops need to be developed and grown. In these cases, relatively low CO_2 avoidance costs are anticipated for the holdings. The implementation of relevant policies would, however, involve relatively high administrative and consulting costs.

– ***Energy conservation***

Rising energy prices and taxation of energy sources lead to energy conservation in agricultural and forestry holdings. Intensified consulting with regard to energy conservation, “energy checks” for agricultural and forestry holdings as well as research and development can contribute to acceleration of these adaptation processes. There are now national funding offers for this in the GAK (Improvement of Agricultural Structure and Coastal Protection).

Under the Integrated Energy and Climate Programme of the Federal government of 05.12.2007, as part of the funding programmes for climate protection and energy efficiency the Federal government plans to set up a federal programme “Energy Efficient Agriculture and Horticulture,” with the aim of sustainably lowering the consumption of fossil heating fuels. The focus is on horticulture, since it uses one third of the fuel energy consumed by agriculture. The Federal government will use approx. € 2.8 million of investment funds to promote the model project ZINEG “Zukunftsinitiative Null-Energie-Gewächshaus” (Zero-Energy Greenhouse Initiative).

– ***Research***

There is in part great need for research to be done to better understand emission events. Quantitative estimates are needed in particular on emissions from soils and to compare systems, holdings and products. The inventories, environmental impact assessments and lifecycle analyses need to be further developed for GHG.

The departmental research of the BMELV was newly structured in 2008 taking greater consideration of the subject of climate protection and the topic complex “climate protection and adaptation to climate change” was adopted in the BMELV 2008 research plan as one of the seven main objectives of departmental research. The individual research institutes are working on the following main tasks for mitigation:

- Inventory of undesired climate-relevant and air-polluting emissions from the agricultural and food industry including studies on the nationwide survey of gaseous emissions from soils and ground vegetation and their assessment.
- Development or further development of methods for lowering undesired climate-relevant emissions from the agriculture and fishing industry.
- Inventory of the fixation of atmospheric carbon dioxide in aboveground and underground biomass.
- Development or further development of conservation of and supplementation of biogenic carbon stocks.
- Further development of renewable resources for sustainable and better substitution of fossil energy sources and fossil/mineral resources as well as the evaluation of technological, economic, ecological and social aspects.

In addition there are increased efforts to make environmental impact assessments of production systems and agricultural products as well as in the analysis of land use changes:

- Identification, evaluation and impact assessment of the effects of various production systems in agriculture, horticulture, forestry, the timber industry, fishing industry and food industry under the aspect of sustainability, including studies on environmental impact assessment.
- Studies on environmental impact assessment of foods and other agricultural products.
- Analysis and projections of land use change and on the optimization of area use.

The increased need for research in the forestry sector to more precisely control mitigation effects is becoming ever more distinct. It must also include the interfaces to the timber industry.

Promoting the use of renewable resources and bioenergy

The Federal government promotes the use of renewable resources in a variety of ways. Some examples are:

- Funding of R&D projects on cascade use and biofuel refineries (project applications for the BMELV announcement are being processed).
- Improving the regulatory conditions for material recycling, to better take the advantages of material recycling in climate gas reduction into account.
- BMELV, BMBF and BMU have launched a joint initiative for a cluster of biofuel refineries in central Germany (funding is not yet definite).
- The provisions of the Biofuel Quota Act require that marketers of fuels market an increasing share of biofuels. In addition, pure biofuels outside the quota are tax-privileged.
- Producers of electric power from regenerative sources are granted fixed feed-in tariffs via the Renewable Energies Act.
- With the market incentive programme, the Federal government promotes investments in plants for heat generation and cooling from regenerative sources.
- Funds from the Renewable Resources programme of the BMELV support research, development and demonstration projects.
- The work of the German Biomass Research Centre in Leipzig contributes to answering questions about all aspects of biomass use.

4 Adaptation

Climate adaptation is a social task to which all actors in industry, science, research, administration, education and politics must contribute. The public authorities have the task of optimizing the prerequisites for efficient adaptation and preventive planning so that the holdings can make intelligent decisions for successful adaptation.

The public authorities must take up special initiative for measures that require greater forethought, planning and action on all levels of farming. These include in particular the areas of research and education and measures in regional planning.

Realizing these adaptation prerequisites is exceedingly urgent in particular for forestry in view of the long production cycles, but also for the areas of plant breeding and regional planning.

When the public authorities have created these prerequisites we can assume that the affected holdings will implement the necessary adaptation measures of their own accord since the proper adaptation measures help cut costs and gain competitive advantages. We also anticipate that the market will react to climate change and offer additional adaptation stimuli.

4.1 Impacts of climate change on agriculture, forestry and the fishing industry

Impacts on agriculture

Agriculture is decisively dependent on the weather and climate and therefore directly affected by climate change. Moreover, the regional differences in the characteristics of climate change that can already be ascertained today may further intensify the impacts. Regions that are too cool or damp under today's conditions for agricultural use may profit from gradual warming and a longer growth period by cultivating crops that were previously limited by warmth. On the other hand in regions that are already warmer or dry today, climate change has rather critical effects.

The rising atmospheric CO_2 level usually has positive effects on plant growth. This CO_2 fertilizing effect should, however, not be overrated, since the impacts of rising temperatures and increasing water shortages are quite critical. Higher atmospheric CO_2 levels not only modify the quantity of plant growth, but also the quality, so that changes in the chemical composition of the plant tissue ranging all the way to changed contents of nutrients and ingredients can be ascertained.

The rise in extreme weather conditions must be seen critically, for they lower yield stability. Increased stress caused by heat, cold, dry or wet conditions can cause to some extent considerable crop losses, in particular if they occur during sensitive phases (such as blossoming or reproductive stages). In addition, damages caused by heavy precipitation, inundation by floodwaters and hail, by higher risk of late frost (chiefly in fruit cultivation) and lower winter hardiness may increase. Furthermore, plant protection problems may be amplified, accompanied by new harmful organisms and a rise in disease pressure by presently inconspicuous harmful organisms. Also, changing soil conditions, in particular increasing dryness during the growth period and higher risk of imbibition particularly in autumn, confront farming with further challenges. In this context, humus conservation is highly important.

In animal production higher summer temperatures can lower feed intake and lessen productivity, thus causing distinct production losses. Climate change is also responsible for the introduction and spread of new diseases spread by animal vectors (e.g. ruminant bluetongue disease). Newly introduced insects can become new vectors. The outbreaks of bluetongue disease in ruminants since mid-August 2006, which are linked to great economic losses, were caused by a virus that can, contrary to earlier findings, also be transmitted by indigenous gnat species. The rodent population, too, which are carriers of zoonotic agents (e.g. tularaemia), are subject to the influence of climate change.

Impacts on forestry

The natural occurrence of tree species is determined by the location as a complex of factors made up chiefly of climate, soil and water. In the past, the forests have been influenced by humans and changed in structure. These forest ecosystems have nonetheless constantly adapted to the environmental conditions. Yet the extent, direction and speed of the present climate change threaten to overtax the adaptability of the forests.

The increasing summer warmth and the rising duration of dry phases put the forests under heat and aridity stress. Moreover the risk of forest fires increases. At the same time, the risk of losses caused by pests, such as the bark beetle, is intensified by greater stress. Mass propagation of specific pests such as the nun moth or May beetle could occur more frequently and previously insignificant or disregarded pests could increase. Here, too, the dry and warmer regions of eastern and southern Germany are especially at risk as well as sites that have a generally poor supply of water or stands that are not very well adapted for other reasons. This applies in particular to the widespread spruce stands, which were cultivated in earlier decades due to their vigorous growth even on sites that were highly risky for them. The spruce is susceptible, depending on location, to storms and aridity stress. In particular, the combination of storms and heat can greatly increase the losses caused by pests, for uprooted and snapped off trees are ideal breeding grounds, for example for the bark beetle. The risk of such damages will, however, increase on principle, even for other tree species.

The mountain forests of the Alps are especially affected by climate change. Here, climate change will have far greater effects than in lowlands. At the same time the risk of natural disasters (strong precipitation, landslides, flooding and rockslides) will increase considerably. This will intensify the importance of the forest for the protection of settlements and infrastructure.

It is important that the forests be adapted to climate change quickly in order to lessen the future risk of increasing calamities and associated disruptions to the timber market and the forest functions. The restructuring of the forest from pure stands to site-adapted, low-risk mixed stands must be pushed ahead. The prerequisite for this is adapted wild stands.

The cultivation recommendations for all tree species must be re-evaluated depending on the sites in a differentiated manner under the aspects of climate change, the long production periods and the associated uncertainties and risks. The methodical procedures and ecological interconnections must be clarified. Presently, recommendations for individual tree species are still debated inconsistently. All of this is a huge challenge for research and practice. Moreover, the transfer of knowledge to the more than 1.3 million forest owners, who must be convinced of the necessity of adaptation measures, is a special task.

If the water and nutrient supplies are adequate, the longer growth periods and the CO_2 fertilization effect could have positive impacts on timber production, but compared to the risks, the positive effects are negligible.

The impacts on flora and fauna and thus the ecosystem conditions in the forest environment are presently not sufficiently assessable. This applies to the relationships between individuals, between tree species, between tree and soil vegetation and between undesired vegetation and pests. Here, too, research is needed. The great uncertainty of scenarios and prognoses, especially in long-term forest production, requires that attention must be paid to broad distribution of risk and large possible variability in courses of action.

Impacts on the fishing industry

Climate change is altering the ecosystems of the North and Baltic Seas for the medium and the long term. On one hand, direct physical and chemical impacts are anticipated (ocean warming, changes in the current system, ocean acidification, influxes in the Baltic Sea and oxygen regime of deepwater) on reproduction, growth and mortality of commercially used fish stocks and on the ecosystem as a whole. On the other hand, in particular the lack of the cold ice winter allows for increased spread of species from more southern maritime areas to the north (e.g. sardines, anchovies and red mullet in the North Sea). Invasive species are increasingly occurring in the plankton and in the benthos of the North and Baltic Seas, which are introduced by shipping traffic and can survive due to the higher water temperatures (example: warty comb jelly in the Baltic Sea). This is accompanied by very different changes with regard to the habitats and food resources of the fish stocks, which cannot yet be adequately assessed. The impacts can differ from species to species and have either positive or negative effects on the productivity of the stocks. The potential changes in the natural ranges of commercial fish species could, under these circumstances, be accompanied by altered accessibility for the fishing industry with corresponding economic impacts, as well as consequences for the energy and CO_2 balances of the fishing industries.

Diadromous species, which require cold waters for spawning (e.g. *Salmonidae*) are particularly affected. Yet, also climate-related changes in sea currents can have effects on spawning migration and larval drift (e.g. eels).

Impacts on the food processing industry

Climate change has hardly any effects on processing in Germany (merely to a certain extent with regard to energy consumption). Changes occur in particular for the basic products intended for processing and their origins, caused by changes in the range of goods and the demand by consumers.

4.2 Adaptive possibilities of agriculture, forestry and the fishing industry

Agriculture

Adaptation in plant production

- Adaptation of sowing times, seed density, distance between rows and crop rotation
- Cultivation of site-adapted varieties
- Cultivation of other crops
- Adaptation of plant protection measures
- Adaptation of soil tillage
- Optimization of water supply and irrigation and drainage systems
- Adaptations in the use of input products (e.g. fertilizers, pesticides)
- Diversification of production
- Special measures on dry sites
    - Conservational soil tillage or deep soil decompaction to promote infiltration
    - Avoidance of unnecessary soil tillage
    - Promotion of root growth
    - Adaptation of spacing and seed depth
    - Adaptation of nitrogen fertilization to water availability
    - Adequate supply of all nutrients and organic substance
    - Conservative use of growth regulators
    - Control of stalk base diseases
    - Avoidance of heat damages (escape strategy)
    - Use of water saving irrigation techniques
    - Adaptation of the irrigation infrastructure

Adaptation measures in plant breeding

- Improvement of heat and aridity stress tolerance in traditional crops, in particular during sensitive development phases, and the provision of seed for (new) heat-loving crops.

- Increasing the growth and yield potentials of crops for optimal utilization of the CO_2 effect on the rate of photosynthesis.
- Ensuring high material recycling quality under changed growth conditions.
- Improving resistances to the anticipated increase in specific harmful organisms and the change to the species spectrum of harmful organisms as a result of climate change.

Adaptation of livestock farming

- Optimization of the (stable) environment with additional cooling systems (e.g. green roof covering; reduction of stable occupancy; agroforestry systems in grazing for shade.)
- Introduction of breeding of heat-tolerant breeds.
- Improvement of nutrient management, especially under heat stress.
- Protection from animal diseases.

Forestry

- Documentation and research of the changes by studies of forestry growth experimental areas, by forest environment monitoring (FUTMON) and inventories (soil and forest condition surveys, BWI), prevention of pests, monitoring of bark beetle and hardwood pests.

- Planting of site-adapted, robust mixed stands of suitable tree species to distribute the risks.
- Converting endangered, non-site-adapted stands into site-adapted, low-risk mixed stands.
- Examination and adaptation of management and use schemes, e.g. stabilizing thinning (stabilization of individual trees and stands).
- Research or description of the impacts of increased use interventions and alteration of rotation periods to increase timber production for the purpose of raising CO_2 fixation.
- Site and forest-related risk analyses and taking them into consideration in stocking plans (lowering the growing-stock goal, diameter goal and height).
- Choice of suitable genetic origins, which are adapted to the present and anticipated site and climate conditions and have high genetic variability, in suitable initial stands preference to natural regeneration (due to their often higher plant numbers and genetic diversity).
- Revision of the site-related tree species recommendations with consideration given to climate change.
- Development of dynamic site mapping with the option of visualizing climatic changes using scenarios.

- Increased consideration of climate aspects in breeding research, origin research, forest conservation, site studies and choice of tree species, studies of competitive behaviour within and between species and tree and forest regeneration, ecosystem climate outcome research and description of the anticipated economic impacts. The results can be documented in stock target maps and risk maps and made available to holdings.
- Intensification of protected forest management and restoration.
- Improvement of water retention (if necessary by closing drainage ditches).

Fishing industry

- Restoring the full reproductive capacities of overfished stocks by adherence to fishing quotas, if necessary revision of management decisions and management plans.
- Improvement of the framework conditions for resource-conserving aquaculture,

For all sectors of agriculture, forestry and fishing

- Development of new types if insurances.

4.3 Federal government measures to support industry in its adaptation process

- Effective plant variety protection law should enable plant breeders to develop adapted crop varieties and, if necessary, crop species.
- Funding for water retention in drought-endangered agriculture and forest landscapes from the GAK.
- Funding the infrastructure for irrigation from the GAK.
- Funding methods for improving soil fertility, soil structure and the natural regulatory mechanisms in the scope of agricultural-environmental measures.
- Knowledge transfer in particular with regard to adapted types of land management, livestock husbandry, animal nutrition and animal health.
- Funding of animal breeding and management measures in livestock husbandry.
  - Inclusion of the attribute “high performance stability for livestock even under suboptimal temperatures (heat)” in performance monitoring and genetic evaluation – and therefore in further breeding work (medium term; breeding organizations with further funding from GAK)
  - Conservation and sustainable use of animal genetic resources in agriculture as farming and breeding reserves in case of adaptation measures that many be required

in future in animal breeding to changing framework conditions (medium term; *Länder* and breeding organizations; expanding the GAK funding principle “Animal Genetic Resources”).

- Building up the scientific decision-making foundations for climate-adapted forest conversion (site mapping, forest plant breeding, provenance research, regional cultivation recommendations, etc.).
- Funding for forestry in the scope of the GAK, e.g.:
    - Conversion of pure stands and of non-site-adapted stands to robust hardwood and mixed stands and use of suitable propagating material.
    - Management of young stands for adaptation to site and stock goals.
    - Prevention and handling of calamities.
    - In addition, examine whether further measures can be adopted, e.g. funding water retention in regions with strong negative water balances.
- Dialogue and knowledge transfer with experts of the *Länder* and forestry.
- Monitoring climate changes to promote understanding for the necessity of adaptation measures.
- Further development of international monitoring of fishing and granting of quotas to the fishing industry
    - Alternative/adaptive management
    - Technical measures
    - Increase the buffer capacity of the resources employed and the fishing industries employing them
    - Establishment of protective zones that increase the resistance of stocks against environmental impacts
    - Promote the formation of reserves for climate-related losses/restructuring
    - Strengthen the connections between the fishing industry and tourism as an alternative income source
    - Alternative steering elements for the fishing industry
- Aquacultures, chiefly with species that can be supplied with vegetable feeds

The departmental research of the BMELV was newly structured in 2008 taking greater consideration of the subject of climate protection and the topic complex “climate protection and adaptation to climate change” was adopted in the BMELV 2008 research plan as one of the seven main objectives of departmental research. The individual research institutes are working on the following main tasks for adaptation:

1. Analysis of the impacts of climate change on agriculture and forestry, horticulture, fishing industry, food industry and on the farming landscapes, rural regions and aquatic

ecosystems including inventories of undesired pollutants (depositions) in agriculture, forestry and the fishing industry.

2. Studies on the characterization, prevention and control of new or increased occurrence of harmful organisms to plants and abiotic damage causes, natural contaminants, animal diseases and zoonoses and their vectors caused by climate change.
3. Analysis and development of methods, cultivation systems, products and services for the adaptation of the agricultural industry to changed climate conditions including their economic and environmental impact evaluation.
4. Inventory of undesired climate-relevant and air-polluting emissions from agriculture and the food industry including studies on national surveys of gaseous emissions from soils and plant growth and their evaluation.
5. Development or further development of the conservation and expansion of biogenic carbon stocks.

Adaptation to climate change has previously been a central task of departmental research for site-adapted agricultural production. To support the coordination of this task, the Working Group on Climate Change was already set up in 1989 http://www.klima-bmvel.de/.

5 Conclusions

The proposed measures take up the chief possibilities for emission reduction and adaptation to climate change. Since emission reduction and adaptation are frequently linked to yield losses or increased costs, it is necessary to weigh interests with regard to the individual measures in order to keep existing conflicts of aims as low as possible. In addition, the climate protection and adaptation measures should be linked to justifiable costs and should avoid mere shifts of emissions, in particular through shifts of production overseas.

In this respect, the following focal points arise:

- Protection of carbon stocks
- Optimization of nitrogen fertilization to improve nitrogen efficiency
- Cascade use of biomass
- Energy conservation and emission reduction in the processing industry, horticulture (greenhouses), in food processing and in the retail food trade
- Drawing up examples for the reduction of emissions per product unit
- Adaptation of water management
- Information about climate-friendly, health-promoting nutrition and sustainable consumption

- Research
- Know-how transfer from research to practice
- Forest conversion to robust mixed forests and forestry management strategies in climate change
- Genetic analyses on the adaptability of forest trees to climate change/targeted origin research