Greenhouse Gas Emission Mitigation through Agriculture

Uwe A. Schneider[a,b] *and Pushpam Kumar*[c]

[a] *Research Unit Sustainability and Global Change, Center for Marine and Atmospheric Sciences, Hamburg University, Germany*

[b] *International Institute for Applied Systems Analysis, Laxenburg, Austria*

[c] *Department of Geography ,University of Liverpool, United Kingdom*

January 15, 2008

This paper has been prepared for a special issue of Choices on agricultural impacts and opportunities concerning climate change and climate change mitigation. The authors are contributors to Chapter 8 “Agriculture” of the Working Group III Report "Mitigation of Climate Change" for Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Greenhouse gas emission mitigation options through agriculture have received increasing attention during the last decade. A relatively detailed topic search within the scientific journal database *Current Content Connect* for 'agriculture', 'climate' or 'global change', and 'mitigation' or 'emission reduction' yields 222 entries within the last 10 years, 151 entries within the last 5 years, and 45 entries in 2007. In *Google Scholar*, the same items match more than 25,000 document links. The 222 peer-reviewed studies, which capture only a fraction of the scientific work, include 139 articles ranging from Alig et al. (1997) to Rokityanskiy et al. (2007), 25 reviews ranging from Paustian et al. (1997) to Smith et al. (2007), and 4 editorials.

This article will not and cannot summarize the wealth of analysis contained in all of these studies. Instead, it draws heavily from the cumulative experience of the authors, who, over the last decade, have written and worked extensively on this topic and were also part of the latest Intergovernmental Panel on Climate Change report on agriculture. We will focus on technologies, economics, and impacts of agricultural mitigation but leave out many aspects of policy design. The paper is structured as follows. The first section hereafter provides an overview over possible mitigation strategies. The next section discusses agricultural mitigation potentials in qualitative terms. Following, we review environmental and societal side effects of agricultural mitigation. Finally, we draw several general conclusions about prospects and limitations of agricultural greenhouse gas emission mitigation efforts.

Mitigation Strategies

Agriculture primarily produces food. Emissions of greenhouse gases from agriculture are influenced by food supply, food type, and farming technologies. Consequently, possible mitigation options involve changes in these three aspects. However, given a growing and in part undernourished human population, global decreases in food supply are not desirable. The second aspect relates to changes in human diets. Greenhouse gas emissions could be reduced by shifts to energy and land sparing diets involving more local, more seasonal, less processed, and more vegetarian food. To put this in perspective, we computed land requirements per calorie by combining land requirements per kg food (Gerbens-Leenes et al. 2002) and nutritional energy contents in calories per kg food (FAO 2004). Results show that one kilocalorie from beef, pork, wheat flour, and potatoes require about 9, 4, 0.4, and 0.3 square meter of land, respectively. However, these values should be used with care because certain land qualities are only suitable for livestock and because proper human diets require more than carbohydrates. Generally, changes in human diets are more relevant for richer countries but they are usually addressed in a human health context and not in a greenhouse gas mitigation context.

The majority of agricultural mitigation assessments relate to the third of the above mentioned aspects: changes in farming methods. These changes also include abandonment of food production in favor of forestry, energy crop plantations, or other non-food uses. The associated emission mitigation strategies are numerous and complex. Available direct options have been grouped into a) sinks, b) emission reductions, and c) avoided emissions in non-agricultural sectors including forestry. Sinks can be interpreted as reversals of past agricultural emissions. They include carbon sequestration in soils and biomass accomplishable through management or land use changes. Agricultural emission reductions comprise methane reductions from ruminant animals, manure, and rice fields; nitrous oxide emission reductions from fertilizer use and manure; and carbon dioxide emission reductions from reduced fossil fuel combustion for agricultural operations and connected businesses. Avoided emissions in other sectors include prevention of deforestation and substitution of fossil fuel by biomass as feedstock for energy and material. Bioenergy strategies generally distinguish biomass for direct combustion to generate electricity and heat and bio-fuel production for substitution of gasoline, diesel, and other transportation fuels. Biomaterial strategies comprise biopolymers, industrial plant oils, and plant based building materials.

The complexity of agricultural options is strongly related to land scarcity and agricultural production intensities. In principal, mitigation could be accomplished by both intensification and extensification. Mitigation through intensification of agricultural production may increase emissions per hectare but at the same time decrease total land requirements and total agricultural emissions. In addition, the spared land can be used for greenhouse gas emission saving non-food options. Mitigation through extensification involves a reduction in emissions per hectare. Total land requirements may moderately increase but total greenhouse gas emissions go down.

Mitigation Potentials

What difference can agriculture make in an emission intensive world heavily dependent on fossil energy sources? In analyzing this question, we will not review empirical emission mitigation estimates but rather provide some guidance for comparison and interpretation of different existing assessments. First, since greenhouse gases constitute a global externality, the potential contribution of agriculture should be accounted at and judged on the global level. Emission mitigation measures, given as local emission savings per hectare, are incomplete and may be misleading. This is discussed in more detail in the next section under leakage. Second, emission reductions should be related to food production levels. If current or higher levels of food quantity and quality should be sustained, much less emissions can be mitigated through agriculture than otherwise. Third, the emission reduction potential of different individual mitigation options from agriculture should be accounted simultaneously. Many –especially land based– mitigation options are mutually exclusive. On the other hand, the heterogeneity of agricultural mitigation options implies that different strategies may be preferred in different regions. If individual strategy assessments are added up, the total mitigation potential may be substantially overstated (Schneider and McCarl). Fourth, agricultural mitigation accounts should comprise the whole spectrum of greenhouse gases. This is especially true for agriculture because some available strategies, while giving huge benefits with respect to one greenhouse gas, may increase emissions of another. Wetland restoration may sequester large amounts of carbon dioxide but at the same time increase methane emissions. Similarly, some of the targeted energy crops are considered to increase greenhouse gas emissions, when considering beneficial carbon offsets together with undesirable increases in nitrous oxide emissions (Crutzen et al.).

Fifth, mitigation options are of little use if they are too costly. In particular, agricultural mitigation potentials have been estimated to be very cost sensitive (McCarl and Schneider). The competitive economic potential of agricultural mitigation strategies at low-costs can fall several magnitudes short of the corresponding technical potential. True mitigation costs include a) direct strategy costs including single adjustment and continuous maintenance costs, b) opportunity costs, c) transaction costs, and d) external social costs and benefits. All costs depend on certain prices and thus, may change over the amount of mitigation effort. If a large cultivated area would be afforested, traditional agricultural commodity production would decrease and prices for associated commodities would go up. Increasing prices for forgone commodity production increases the economic disincentive for additional afforestation. Transaction costs relate to monitoring, verification, and enforcement. The costs of verification include the impacts of uncertainties and vulnerabilities. Risk averse preferences imply that uncertain and vulnerable emission reductions have a lower value than certain and permanent emission reductions.

Mitigation Externalities

Mitigation policies which induce agricultural mitigation efforts yield intended and external effects. Intended or targeted effects include reduced greenhouse gas concentrations, which may slow down climate change, and increased energy security. The focus of this section is mitigation externalities related to agriculture. Particularly, we consider three types of unintended and usually unattended side effects: a) greenhouse gas emission impacts, b) other environmental impacts, and c) societal impacts. Unintended greenhouse gas emission impacts are also referred to as emission leakage. Emission leakage is often thought of as leakage over space. If a climate policy regulates emissions in some countries, emission intensive production may shift from these countries to unregulated countries, thereby increasing their emissions. More generally, emission leakage applies to any partially implemented climate policy be it partial with respect to space, time, greenhouse gases, or technologies. The magnitude of emission leakage depends both on the scope of a climate policy and on characteristics of the chosen mitigation strategies. In principal, if mitigation strategies are neutral to agricultural commodity supply, leakage is negligible. Examples of relatively neutral strategies include carbon sequestration via reduced tillage, moderate crop residue use for bio-energy generation, livestock manure management, use of low-emission fertilizers, and crop-demand based fertilization. Land intensive mitigation strategies, on the other hand, have a high leakage potential because these strategies decrease traditional agricultural commodity supply and provide incentives to expand agriculture elsewhere. Thus, high leakage potentials exist for afforestation of agricultural land, dedicated energy crop plantations and wetland restoration.

Non-greenhouse gas environmental side effects include impacts on soil, water, ecosystems and the flow of ecosystem services. Again, depending on the characteristics of the chosen mitigation strategies, impacts may be beneficial or detrimental. Because soil quality correlates positively with humus levels, soil organic carbon enhancing mitigation strategies are beneficial. Restoration of degraded lands and wetlands as well as tillage reducing systems is generally considered beneficial for soil quality. On the other hand, if mitigation measures reduce the amount of organic or mineral fertilizer input, soil quality will decrease. Such measures include extensive crop residue removal for bio-energy generation and manure digestion. The on-site impact of higher cropping intensities on soil quality is ambiguous because both nutrient inputs and nutrient removals are increased and the resultant of the two would determine the direction of impact. Furthermore, agricultural intensification of agriculture could increase soil salinity, water-logging and mono cropping as has been experienced in many parts of the developing world, for example in India after the green revolution. Water quality impacts are linked to soil impacts. Higher soil organic carbon levels improve moisture and nutrient holding capacities and thus, decrease nutrient emissions into surface, sub-surface, and ground water. Fertilizer based mitigation options, which aim at minimizing excess fertilizer, are likely to reduce water pollution. On the other hand, if tillage reductions increase herbicide applications, water quality will decrease.

Mitigation efforts have synergies and trade-offs with ecosystems especially cultivated ecosystems. Mitigation impacts the condition and resilience of cultivated ecosystems which in turn decide the flow of the ecosystem services critical for agricultural inputs and outputs. Mitigation here works as driver of change for the cultivated ecosystems (MA 2005). Overall, whether ecosystem co-effects are positive or negative depends foremost on how mitigation influences the size of nature reserves. The establishment of permanent native forests or restorations of wetlands for carbon sequestration are beneficial for ecosystems. Trade-offs exist, if homogeneous energy crop or tree plantations replace native forests. An environmental worst case scenario would be where subsidized energy crop plantations with a positive net emission balance across all greenhouse gases irreversibly replace species-rich rain forests. If mitigation efforts reduce agricultural intensities on grasslands, pastures, and croplands, some on-site ecological benefits are possible. However, intensity reductions increase land scarcity and thus increase pressure on nature reserves elsewhere.

The third category of side effects from agricultural mitigation involves social welfare externalities related to food, water, energy, health, employment, extreme events, and landscape. Food security deceases if agricultural mitigation efforts a) consume land suitable for food production, i.e. via dedicated energy crop plantations, wetland restoration, or afforestation; or b) lead to a reduction in land productivity, i.e. via crop residue removal or livestock manure digestion thereby decreasing organic fertilizers. Synergies between mitigation and food supply are possible through soil carbon sequestration on degraded farmland. Wasteland could also be used for fish production as demonstrated in Israel, Syria and other parts of Mediterranean Africa. Changes in global food production patterns are likely to affect malnutrition and obesity. Malnutrition increases if agricultural mitigation makes food relatively more expensive for poor people. However, if higher food prices are coupled with beneficial changes in employment and income distribution, alleviations of malnutrition are possible. Furthermore, increasing land scarcity will shift the supply equilibrium from land intensive food commodities, i.e. livestock products, towards land friendly commodities, i.e. crop products. This may worsen some nutritional deficiencies in poor countries but reduce obesity in richer countries. However, these are tentative conjectures. The real direction of outcome is context specific and depends on the strength of the cause and effect relationship between the forces described earlier

Water security impacts comprise changes in regional agricultural water use resulting from greenhouse gas emission mitigation efforts. Land intensive mitigation strategies lead to increases in irrigation intensities for traditional crops (McCarl and Schneider). In addition, negative water impacts are expected from large-scale energy crop plantations (Berndes). Finally, societal side effects may involve recreational and civil protection impacts through landscape restructuring. For example, restored wetlands may increase flood protection. It can also bring nutrients, provide water storage facilities especially in arid and semi arid areas and contribute towards bioremediation.

Conclusions

What benefits can society reap from agricultural mitigation options despite the described complexities, variations, and uncertainties? Which strategies should be pursued at which level? Alternatively, what mitigation strategies should agriculture not become engaged to? In answering these questions, we will draw several general conclusions.

1) The socially optimal mitigation strategy mix minimizes the social costs of emission mitigation per calorie. Inefficiencies arise if a) technologies are regulated instead of emissions, b) non-carbon greenhouse gas effects are excluded, c) environmental and societal side effects are ignored, and d) uncertainties, vulnerabilities, and irreversibilities are not properly integrated.
2) The complexity of land use impacts on food, water, energy, climate, and ecosystems calls for integrated assessments. Otherwise, today's solution may become tomorrow's problem.

3) Agriculture has a limited potential to provide low cost emission reductions. Higher emission mitigation targets are land intensive and due to land scarcity lead to substantial increases of marginal mitigation costs.
4) Emission leakage leading to increased deforestation of native forests or destruction of wetlands or other valuable ecosystems could become a serious drawback to agricultural mitigation efforts. Irreversible biodiversity losses coupled with positive overall net emissions of greenhouse gases would essentially imply an environmental loss-loss strategy. Such situations could arise with unconditional promotion of dedicated energy crops or large-scale afforestation programs in suitable cropland areas. Similarly, on-site greenhouse gas emission reductions from low input cropping systems may be more than offset through emission leakage.
5) Measures, which relax land scarcity, simultaneously decrease the potential for emission leakage and negative environmental side effects. Such measures include on the supply side restoration of degraded lands and emission friendly yield improvements, and on the demand side promotion of energy friendly diets.
6) Non-carbon emissions from crop and livestock production are important but very costly to measure and regulate.

References

Alig,R., D.Adams, B.McCarl, J.M.Callaway, and S.Winnett. 1997. "Assessing effects of mitigation strategies for global climate change with an intertemporal model of the US forest and agriculture sectors." *Critical Reviews in Environmental Science and Technology*. 27:S97-S111.

Berndes,G. 2002. "Bioenergy and water--the implications of large-scale bioenergy production for water use and supply." *Global Environmental Change*. 12:253-271.

Crutzen,P.J., A.R.Mosier, K.A.Smith, and W.Winiwarter. 2007. "N2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels." *Atmos.Chem.Phys.Discuss.* 7:11191-11205.

FAO. 2004. Summary of Food and Agricultural Statistics 2003. (Food and Agricultural Organization, Rome, 2004).

Gerbens-Leenes,P.W., S.Nonhebel, and W.P.M.F.Ivens. 2002. "A method to determine land requirements relating to food consumption patterns." *Agriculture, Ecosystems & Environment*. 90:47-58.

McCarl,B.A. and U.A.Schneider. 2001. "Climate change - Greenhouse gas mitigation in US agriculture and forestry." *Science*. 294:2481-2482.

Millennium Ecosystem Assessment (MA). 2005. Findings of the Condition and Trend Working Group, Ch26: Cultivated Ecosystems, Island Press, Washington DC.

Paustian,K., O.Andren, H.H.Janzen, R.Lal, P.Smith, G.Tian, H.Tiessen, M.Van Noordwijk, and P.L.Woomer. 1997. "Agricultural soils as a sink to mitigate CO2 emissions." *Soil Use and Management*. 13:230-244.

Rokityanskiy,D., P.C.Beniez, F.Kraxner, I.McCallum, M.Obersteiner, E.Rametsteiner, and Y.Yamagata. 2007. "Geographically explicit global modeling of land-use change, carbon sequestration, and biomass supply." *Technological Forecasting and Social Change*. 74:1057-1082.

Schneider,U.A. and B.A. McCarl. 2006. "Appraising agricultural greenhouse gas mitigation potentials: Effects of alternative assumptions. " *Agricultural Economics*. 35(3):277-287

Smith,P., D.Martino, Z.C.Cai, D.Gwary, H.Janzen, P.Kumar, B.McCarl, S.Ogle, F.O'Mara, C.Rice, B.Scholes, O.Sirotenko, M.Howden, T.McAllister, G.X.Pan, V.Romanenkov, U.A.Schneider, and S.Towprayoon. 2007. "Policy and technological constraints to implementation of greenhouse gas mitigation options in agriculture." *Agriculture Ecosystems & Environment*. 118:6-28.

Working Papers

Research Unit Sustainability and Global Change

Hamburg University and Centre for Marine and Atmospheric Science

Schneider, U.A. and P. Kumar (2008), Mitigation through Agriculture, **FNU-155**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J. and S. Wagner (2008), *Climate Change and Violent Conflict in Europe over the Last Millennium,* **FNU-154**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Schleupner, C. (2007).*Regional Spatial Planning Assessments for Adaptation to accelerated sea level rise – an application to Martinique's coastal zone,* **FNU-153**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Schleupner, C. (2007). *Evaluating the Regional Coastal Impact Potential to Erosion and Inundation caused by Extreme Weather Events and Tsunamis,* **FNU-152**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Rehdanz, K. (2007), *Species diversity and human well-being: A spatial econometric approach,* **FNU-151,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Osmani, D. and R.S.J. Tol (2007), *A short note on joint welfare maximization assumption,* **FNU-150,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Osmani, D. and R.S.J. Tol (2007), *Towards Farsightedly Stable International Environmental Agreements: Part Two,* **FNU-149,** Hamburg University and Centre for Atmospheric Science, Hamburg. download

Ruane, F.P. and R.S.J. Tol (2007), *Academic Quality, Power and Stability: An Application to Economics in the Republic of Ireland*, **FNU-148**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J. (2007), *A Rational, Successive g-Index Applied to Economics Departments in Ireland*, **FNU-147**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J. (2007), *Of the h-Index and its Alternatives: An Application to the 100 Most Prolific Economists*, **FNU-146**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Yohe, G.W. and R.S.J. Tol (2007), *Precaution and a Dismal Theorem: Implications for Climate Policy and Climate Research*, **FNU-145**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J. (2007), *The Social Costs of Carbon: Trends, Outliers, and Catastrophes*, **FNU-144**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J. (2007), *The Matthew Effect Defined and Tested for the 100 Most Prolific Economists*, **FNU-143**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Berrittella, M., K. Rehdanz, R.S.J. Tol and J. Zhang (2007), *The Impact of Trade Liberalisation on Water Use: A Computable General Equilibrium Analysis*, **FNU-142**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Lyons, S., K. Mayor and R.S.J. Tol (2007), *Convergence of Consumption Patterns during Macroeconomic Transition: A Model of Demand in Ireland and the OECD*, **FNU-141**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Osmani, D. and R.S.J. Tol (2007), *Towards Farsightedly Stable International Environmental Agreements: Part One,* **FNU-140**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download.

Rehdanz, K. and S. Stöwhase (2007), *Cost Liability and Residential Space Heating Expenditures of Welfare Recipients in Germany*, **FNU-139**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Schleupner, C. and P.M. Link (2007), *Potential impacts on bird habitats in Eiderstedt (Schleswig-Holstein) caused by agricultural land use changes*, **FNU-138**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Link, P.M. and C. Schleupner (2007), *Agricultural land use changes in Eiderstedt: historic developments and future plans*, **FNU-137**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Anthoff, D., R.J. Nicholls and R.S.J. Tol (2007), *Global Sea Level Rise and Equity Weighting*, **FNU-136**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Schleupner, C. (2007), *Wetland Distribution Modelling for Optimal Land Use Options in Europe*, **FNU-135**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Mayor, K. and R.S.J. Tol (2007), *The Impact of the EU-US Open Skies Agreement on International Travel and Carbon Dioxide Emissions*, **FNU-134**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Schneider, U.A., M. Obersteiner, and E. Schmid (2007), *Agricultural adaptation to climate policies and technical change*, **FNU-133**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Lychnaras, V. and U.A. Schneider (2007), *Dynamic Economic Analysis of Perennial Energy Crops - Effects of the CAP Reform on Biomass Supply in Greece*, **FNU-132**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Mayor, K. and R.S.J. Tol (2007), *The Impact of the UK Aviation Tax on Carbon Dioxide Emissions and Visitor Numbers*, **FNU-131**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Ruane, F. and R.S.J. Tol (2007), *Refined (Successive) h-indices: An Application to Economics in the Republic of Ireland*, **FNU-130**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Yohe, G.W., R.S.J. Tol and D. Murphy (2007), *On Setting Near-Term Climate Policy as the Dust Begins to Settle: The Legacy of the Stern Review*, **FNU-129**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Maddison, D. and K. Rehdanz (2007), *Are Regional Differences in Utility Eliminated over Time? Evidence from Germany*, **FNU-128**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Anthoff, D. and R.S.J. Tol (2007), *On International Equity Weights and National Decision Making on Climate Change*, **FNU-127**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

de Bruin, K.C., R.B. Dellink and R.S.J. Tol (2007), *AD-DICE: An Implementation of Adaptation in the DICE Model*, **FNU-126**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J. and G.W. Yohe (2007), *The Stern Review: A Deconstruction*, **FNU-125** , Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Keller, K., L.I. Miltich, A. Robinson and R.S.J. Tol (2006), *How Overconfident Are Current Projections of Carbon Dioxide Emissions?*, **FNU-124**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Cowie, A., U.A. Schneider and L. Montanarella (2006), *Potential synergies between existing multilateral environmental agreements in the implementation of Land Use, Land Use Change and Forestry activities*, **FNU-123,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Kuik, O.J., B. Buchner, M. Catenacci, A. Goria, E. Karakaya and R.S.J. Tol (2006), *Methodological Aspects of Recent Climate Change Damage Cost Studies*, **FNU-122**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Anthoff, D., C. Hepburn and R.S.J. Tol (2006), *Equity weighting and the marginal damage costs of climate change*, **FNU-121**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J. (2006), *The Impact of a Carbon Tax on International Tourism*, **FNU-120**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download An update with the latest policy proposals.

Rehdanz, K. and D. Maddison (2006), *Local Environmental Quality and Life-Satisfaction in Germany*, **FNU-119,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tanaka, K., Tol, R.S.J., Rokityanskiy, D., O'Neill, B.C. and M. Obersteiner (2006), *Evaluating Global Warming Potentials as Historical Temperature Proxies: an Application of ACC2 Inverse Calculation*, **FNU-118**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Berrittella, M., K. Rehdanz and R.S.J. Tol (2006), *The Economic Impact of the South-North Water Transfer Project in China: A Computable General Equilibrium Analysis*, **FNU-117,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol,R.S.J. (2006), *Why Worry about Climate Change? A Research Agenda*, **FNU-116,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Hamilton,J.M. and R.S.J. Tol (2006), *The Impact of Climate Change on Tourism in Germany,the UK and Ireland: A Simulation Study*, **FNU-115,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Schwoon, M., F. Alkemade, K. Frenken and M.P. Hekkert (2006), *Flexible transition strategies towards future well-to-wheel chains: an evolutionary modelling approach*, **FNU-114,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Ronneberger, K., L. Criscuolo, W.Knorr, R.S.J. Tol (2006), *KLUM@LPJ: Integrating dynamic land-use decisions into a dynamic global vegetation and crop growth model to assess the impacts of a changing climate. A feasibility study for Europe*, **FNU-113**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Schwoon, M. (2006), *Learning-by-doing, Learning Spillovers and the Diffusion of Fuel Cell Vehicles,* **FNU-112,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Strzepek, K.M., G.W. Yohe, R.S.J. Tol and M. Rosegrant (2006), *The Value of the High Aswan Dam to the Egyptian Economy*, **FNU-111**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Schwoon, M. (2006), *A Tool to Optimize the Initial Distribution of Hydrogen Filling Stations*, **FNU-110**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J., K.L. Ebi and G.W. Yohe (2006), *Infectious Disease,Development, and Climate Change: A Scenario Analysis*, **FNU-109**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Lau, M.A. (2006), *An analysis of the travel motivation of tourists from the People's Republic of China*, **FNU-108**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Lau, M.A. and R.S.J. Tol (2006), *The Chinese are coming – An analysis of the preferences of Chinese holiday makers at home and abroad*, **FNU-107**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Röckmann, C., R.S.J. Tol, U.A. Schneider, and M.A. St.John (2006), *Rebuilding the Eastern Baltic cod stock under environmental change - Part II: The economic viability of a marine protected area,* **FNU-106**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Ronneberger, K., M. Berrittella, F. Bosello and R.S.J. Tol (2006), *KLUM@GTAP: Introducing biophysical aspects off-land-use decisions into a general equilibrium model. A coupling* *experiment*, **FNU-105**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Link, P.M. and R.S.J. Tol (2006), *Economic impacts on key Barents Sea fisheries arising from changes in the strength of the Atlantic thermohaline circulation*, **FNU-104**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Link, P.M. and R.S.J. Tol (2006), *The economic impact of a shutdown of the Thermohaline Circulation: an application of FUND*, **FNU-103**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J. (2006), *Integrated Assessment Modelling*, **FNU-102**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J. (2006), *Carbon Dioxide Emission Scenarios for the USA*, **FNU-101**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J., S.W. Pacala and R.H.Socolow (2006), *Understanding Long-Term Energy Use and Carbon Dioxide Emissions in the USA*, **FNU-100**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg.download

Sesabo, J.K, H. Lang and R.S.J. Tol (2006), *Perceived Attitude and Marine Protected Areas(MPAs) establishment: Why households' characteristics matters in Coastal resources conservation initiatives in Tanzania*, **FNU-99**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J. (2006), *The Polluter Pays Principle and Cost-Benefit Analysis of Climate Change: An Application of FUND*, **FNU-98**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J. and G.W. Yohe (2006), *The Weakest Link Hypothesis for Adaptive Capacity: An Empirical Test*, **FNU-97**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Berrittella, M., K. Rehdanz, R. Roson and R.S.J. Tol (2005), *The Economic Impact of Water Pricing: A Computable General Equilibrium Analysis*, **FNU-96**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Sesabo, J.K and R.S.J. Tol (2005), *Technical Efficiency and Small-scale Fishing Households in Tanzanian coastal Villages: An Empirical Analysis*, **FNU-95**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Lau, M.A. (2005), *Adaptation to Sea-level Rise in the People's Republic of China – Assessing the Institutional Dimension of Alternative Organisational Frameworks*, **FNU-94,**Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Berrittella, M., A.Y. Hoekstra, K. Rehdanz, R. Roson and R.S.J. Tol (2005), *The Economic Impact of Restricted Water Supply: A Computable General Equilibrium Analysis*, **FNU-93**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J. (2005), *Europe's Long Term Climate Target: A Critical Evaluation*, **FNU-92**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Hamilton, J.M. (2005), *Coastal Landscape and the Hedonic Price of Accomodation*, **FNU-91**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Hamilton, J.M., D.J. Maddison and R.S.J. Tol (2005), *Climate Preferences and Destination Choice: A Segmentation Approach*, **FNU-90,**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Zhou,Y. and R.S.J. Tol (2005), *Valuing the health impacts from particulate air pollution in Tianjin*, **FNU-89**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Röckmann,C. (2005), *International cooperation for sustainable fisheries in the Baltic Sea*, **FNU-88**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Ceronsky, M., D. Anthoff, C. Hepburn and R.S.J. Tol (2005), *Checking the price tag on catastrophe: The social cost of carbon under non-linear climate response,* **FNU-87,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Zandersen, M. and R.S.J. Tol (2005), *A Meta-analysis of Forest Recreation Values in Europe*, **FNU-86,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg.download

Heinzow, T., R.S.J. Tol and B. Brümmer (2005), *Offshore-Windstromerzeugung in der Nordsee - eine ökonomische und ökologische Sackgasse?,* **FNU-85**,Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Röckmann, C., U.A. Schneider, M.A.St.John, and R.S.J. Tol (2005), *Rebuilding the Eastern Baltic cod stock under environmental change - a preliminary approach using stock, environmental, and management constraints*, **FNU-84**, Hamburg University and Centre for Marineand Atmospheric Science, Hamburg, forthcoming in Natural Resource Modeling, spring 2007. download

Tol, R.S.J. and G.W. Yohe (2005), *Infinite uncertainty, forgotten feedbacks, and cost-benefit analysis of climate policy*, **FNU-83**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Osmani, D. and Tol, R.S.J. (2005), *The case of two self-enforcing international agreements for ironmental protection*, **FNU-82**,Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Schneider, U.A. and B.A. McCarl (2005), *Appraising Agricultural Greenhouse Gas Mitigation Potentials: Effects of Alternative Assumptions*, **FNU-81**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Zandersen, M., M. Termansen, and F.S. Jensen, (2005), *Valuing new forest sites over time: the case of afforestation and recreation in Denmark*, **FNU-80**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Guillerminet, M.-L. and R.S.J. Tol (2005), *Decision Making under Catastrophic Risk and Learning: the Case of the Possible Collapse of the West Antarctic Ice Sheet*, **FNU-79,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Nicholls, R..J., R.S.J. Tol and A.T. Vafeidis (2005), *Global Estimates of the Impact of a Collapse of the West-Antarctic Ice Sheet: An application of FUND*, **FNU-78,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Lonsdale,K., T.E. Downing, R.J. Nicholls, D. Parker, A.T. Vafeidis, R. Dawson and J.W.Hall (2005), *Plausible responses to the threat of rapid sea-level rise for the Thames Estuary*, **FNU-77,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Poumadère,M., C. Mays, G. Pfeifle with A.T. Vafeidis (2005), *Worst Case Scenario and Stakeholder Group Decision: A 5-6 Meter Sea Level Rise in the Rhone Delta*, *France*, **FNU-76,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Olsthoorn, A.A., P.E. van der Werff, L.M. Bouwer and D. Huitema (2005), *Neo-Atlantis: Dutch Responses to Five Meter Sea Level Rise*, **FNU-75,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Toth, F.L. and E. Hizsnyik (2005), *Managing the inconceivable: Participatory assessments of impacts and responses to extreme climate change*, **FNU-74,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Kasperson, R.E. M.T. Bohn and R.Goble (2005), *Assessing the risks of a future rapid large sea levelrise: A review*, **FNU-73,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Schleupner, C. (2005), *Evaluation of coastal squeeze and beach reduction and its consequences for the Caribbean island Martinique*, **FNU-72**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg.download

Schleupner, C. (2005), *Spatial Analysis As Tool for Sensitivity Assessment of Sea Level Rise Impacts on Martinique*, **FNU-71**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Sesabo, J.K. and R.S.J. Tol (2005), *Factors affecting Income Strategies among households in Tanzanian Coastal Villages: Implication for Development-Conservation Initiatives*, **FNU-70**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Fisher, B.S., G. Jakeman, H.M. Pant, M. Schwoon. and R.S.J. Tol (2005), *CHIMP: A Simple Population Model for Use in Integrated Assessment of Global Environmental Change*, **FNU-69,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Rehdanz, K. and R.S.J. Tol (2005), *A No Cap But Trade Proposal for Greenhouse Gas Emission Reduction Targets for Brazil, China and India*, **FNU-68,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Zhou, Y. and R.S.J. Tol (2005), *Water Use in China's Domestic, Industrial and Agricultural Sectors: An Empirical Analysis*, **FNU-67**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. fileadmin/fnu-files/publication/working-papers/WD_ZhouFNU67.pdfdownload

Rehdanz, K. (2005), *Determinants of residential space heating expenditures in Germany*, **FNU-66**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Ronneberger, K., R.S.J. Tol and U.A.Schneider (2005), *KLUM: A simple model of global agricultural land use as a coupling tool of economy and vegetation*, **FNU-65**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J. (2005), *The Benefits of Greenhouse Gas Emission Reduction: An Application of FUND*, **FNU-64**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg.download

Röckmann, C., M.A. St.John, U.A.Schneider, F.W. Köster, F.W. and R.S.J. Tol (2006), *Testing the implications of a permanent or seasonal marine reserve on the population dynamics of Eastern Baltic cod under varying environmental conditions*, **FNU-63-revised**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Letsoalo, A., J. Blignaut, T. deWet, M. de Wit, S. Hess, R.S.J. Tol and J. van Heerden (2005), *Triple Dividends of Water Consumption Charges in South Africa*, **FNU-62**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Zandersen, M., M. Termansen and F.S. Jensen (2005), *Benefit Transfer over Time of Ecosystem Values: the Case of Forest Recreation*, **FNU-61**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Rehdanz, K., R.S.J. Tol and P. Wetzel (2005), *Ocean Carbon Sinks and International Climate Policy*, **FNU-60,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg.download

Schwoon, M. (2005), *Simulating The Adoption of Fuel Cell Vehicles*, **FNU-59,** Hamburg University and Centre for Marine and atmospheric Science, Hamburg. download

Bigano, A., J.M. Hamilton and R.S.J.Tol (2005), *The Impact of Climate Change on Domestic and International Tourism: A Simulation Study*, **FNU-58**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Bosello, F., R. Roson and R.S.J. Tol(2004), *Economy-wide estimates of the implications of clima techange: Human health*, **FNU-57,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg.download

Hamilton, J.M. and M.A. Lau (2004), *The role of climate information in tourist destination choice decision-making*, **FNU-56,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Bigano, A., J.M. Hamilton and R.S.J. Tol (2004), *The impact of climate on holiday destination choice*, **FNU-55**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Bigano, A., J.M. Hamilton, M. Lau, R.S.J. Tol and Y. Zhou (2004), *A global database of domestic and international tourist numbers at national and subnational level*, **FNU-54**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Susandi, A. and R.S.J. Tol(2004), Impact *of international emission reduction on energy and forestry sector of Indonesia*, **FNU-53**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Hamilton, J.M. and R.S.J. Tol (2004), *The Impact of Climate Change on Tourism and Recreation*, **FNU-52,**Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Schneider, U.A. (2004), *Land Use Decision Modeling with Soil Status Dependent Emission Rates*, **FNU-51,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Link, P.M., U.A. Schneider and R.S.J. Tol. (2004), *Economic impacts of changes in fish population dynamics: the role of the fishermen's harvesting strategies*, **FNU-50**, Centre for Marine and Climate Research, Hamburg University,Hamburg. download

Berritella, M., A. Bigano, R. Roson and R.S.J. Tol (2004), *A General Equilibrium Analysis of Climate Change Impacts on Tourism*, **FNU-49**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Tol, R.S.J. (2004), *The Double Trade-Off between Adaptation and Mitigation for Sea Level Rise: An Application of FUND*, **FNU-48**,Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Erdil, E. and I.H. Yetkiner (2004), *A Panel Data Approach for Income-Health Causality*, **FNU-47**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Tol, R.S.J. (2004), *Multi-Gas Emission Reduction for Climate Change Policy: An Application of FUND*, **FNU-46**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg.download

Tol, R.S.J. (2004), *Exchange Rates and Climate Change: An Application of FUND*, **FNU-45**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. download

Gaitan, B., R.S.J. Tol and I.H. Yetkiner (2004), *The Hotelling's Rule Revisited in a Dynamic General Equilibrium Model*, **FNU-44**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Rehdanz, K. and R.S.J. Tol (2004), *On Multi-Period Allocation of Tradable Emission Permits*, **FNU-43**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Link, P.M. and R.S.J. Tol (2004), *Possible Economic Impacts of a Shutdown of the Thermohaline Circulation:An Application of FUND*, **FNU-42**,Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Zhou, Y. and R.S.J. Tol (2004), *Evaluating the costs of desalination and water transport*, **FNU-41**, revised, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Lau, M. (2004), *Küstenzonenmanagement in der Volksrepublik China und Anpassungsstrategien an den Meeresspiegelanstieg,* **FNU-40**,Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Rehdanz, K. and Maddison, D. (2004), *The Amenity Value of Climate to German Households*, **FNU-39 revised**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Bosello,F., Lazzarin, M., Roson, R. and Tol, R.S.J. (2004), *Economy-wide Estimates of the Implications of Climate Change: Sea Level Rise*, **FNU-38**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Schwoon, M. and R.S.J. Tol. (2004), *Optimal CO2-abatement with socio-economic inertia and induced technological change*, **FNU-37**,Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Hamilton, J.M., D.J. Maddison and R.S.J. Tol (2004), *The Effects of Climate Change on International Tourism*, **FNU-36**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Hansen, O. and R.S.J. Tol (2003), *A Refined Inglehart Index of Materialism and Postmaterialism*, **FNU-35**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Heinzow, T. and Tol, R.S.J. (2003), *Prediction of Crop Yields across four Climate Zones in Germany: An Artificial Neural Network Approach*, **FNU-34,** Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Tol, R.S.J. (2003), *Adaptation and Mitigation: Trade-offs in Substance and Methods*, **FNU-33,** Centre for Marine and ClimateResearch, Hamburg University, Hamburg. download

Tol, R.S.J. and T. Heinzow (2003), *Estimates of the External and Sustainability Costs of Climate Change*, **FNU-32,** Centre for Marineand Climate Research, Hamburg University, Hamburg. download

Hamilton, J.M., D.J. Maddison and R.S.J. Tol (2003), Climate *change and international tourism: a simulation study*, **FNU-31**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Link, P.M. and R.S.J. Tol (2003), *Economic impacts of changes in population dynamics of fish on the fisheries in the Barents Sea*, Research Unit Sustainability and Global Change **FNU-30**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Link, P.M. (2003), *Auswirkungen populationsdynamischer Veränderungen in Fischbeständen auf die Fischereiwirtschaft in der Barentssee,Research Unit Sustainability and Global*

Change, **FNU-29**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Lau, M.A. (2003), *Integrated Coastal Zone Management in the People's Republic of China – An Assessment of Structural Impacts on Decision-making Processes, Research Unit Sustainability and Global Change,* **FNU-28(revised)**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Lau, M.A. (2003), *Coastal Zone Management in the People's Republic of China – A Unique Approach?*, **FNU-27**, Centre for Marine and Climate Research, Hamburg University, Hamburg. China Environment Series, Issue 6, pp. 120-124; download

Roson, R. and R.S.J. Tol (2003), *An Integrated Assessment Model of Economy-Energy-Climate – The Model Wiagem: A Comment*, **FNU-26**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Yetkiner, I.H. (2003), *Is There An Indispensable Role For Government During Recovery From An Earthquake? A Theoretical Elaboration*, **FNU-25**, Centre for Marineand Climate Research, Hamburg University, Hamburg. download

Yetkiner, I.H. (2003), *A Short Note On The Solution Procedure of Barro And Sala-i-Martin forRestoring Constancy Conditions*, **FNU-24**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Schneider, U.A. and B.A. McCarl (2003), *Measuring Abatement Potentials When Multiple Change is Present: The Case of Greenhouse Gas Mitigation in U.S. Agriculture and Forestry*, **FNU-23**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Zhou, Y. and R.S.J. Tol (2003), *The Implications of Desalination for Water Resources in China:An Economic Perspective*, **FNU-22**, Centre for Marineand Climate Research, Hamburg University, Hamburg. download

Yetkiner, I.H., de Vaal, A., and van Zon, A. (2003), *The Cyclical Advancement of Drastic Technologies*, **FNU-21**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Rehdanz, K. and D. Maddison (2003), *Climate and Happiness*, **FNU-20**,Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Tol, R.S.J. (2003), *The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties*, **FNU-19**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Lee, H.C., B.A. McCarl, U.A.Schneider, and C.C. Chen (2003), *Leakage and Comparative Advantage Implications of Agricultural Participation in Greenhouse Gas Emission Mitigation*, **FNU-18**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Schneider, U.A. and B.A. McCarl(2003), *Implications of a Carbon Based Energy Tax for U.S. Agriculture,* **FNU-17**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Tol, R.S.J. (2002), *Climate, Development and Malaria: An Application of FUND*, **FNU-16**,Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Hamilton, J.M. (2002), *Climate and the Destination Choice of German Tourists*, **FNU-15 (**revised), Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Tol, R.S.J. (2002), *Technology Protocols for Climate Change: An Application of FUND*, **FNU-14**,Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Rehdanz, K (2002), *Hedonic Pricing of Climate Change Impacts to Households in Great Britain*, **FNU-13**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Tol, R.S.J. (2002), *Emission Abatement versus Development as Strategies to Reduce Vulnerability to Climate Change: An Application of FUND*, **FNU-12** (revised), Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Rehdanz, K. and R.S.J Tol (2002), *On National and International Trade in Greenhouse Gas Emission Permits,* **FNU-11 (revised)**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Fankhauser, S. and R.S.J. Tol(2001), *On Climate Change and Growth*, **FNU-10 (revised)**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Tol, R.S.J. and R. Verheyen (2001), *Liability and Compensation for Climate Change Damages – A Legal and Economic Assessment*, **FNU-9**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Yohe, G. and R.S.J. Tol (2001), *Indicators for Social and Economic Coping Capacity – Moving Toward at Working Definition of Adaptive Capacity*, **FNU-8**,Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Kemfert, C., W. Lise and R.S.J. Tol (2001), *Games of Climate Change with International Trade*, **FNU-7**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Tol, R.S.J., W. Lise, B. Morel and B.C.C. van der Zwaan (2001), *Technology Development and Diffusion and Incentives to Abate Greenhouse Gas Emissions*, **FNU-6**, Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Kemfert, C. and R.S.J. Tol (2001), *Equity, International Trade and Climate Policy*, **FNU-5**,Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Tol, R.S.J., Downing T.E., Fankhauser S., Richels R.G. and Smith J.B. (2001), *Progress in Estimating the Marginal Costs of Greenhouse Gas Emissions*, **FNU-4**,Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Tol, R.S.J. (2000), *How Large is the Uncertainty about Climate Change?,* **FNU-3**,Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Tol, R.S.J., S.Fankhauser, R.G. Richels and J.B. Smith (2000), *How Much Damage Will Climate Change Do? Recent Estimates*, **FNU-2**,Centre for Marine and Climate Research, Hamburg University, Hamburg. download

Lise, W. and R.S.J. Tol (2000), *Impact of Climate on Tourism Demand, Research Unit Sustainability and Global Change,* **FNU-1**,Centre for Marine and Climate Research, Hamburg University, Hamburg. download