Project No 518294 SES6

CASES

Cost Assessment of Sustainable Energy Systems

Instrument: Co-ordination Action

Thematic Priority: Sustainable Energy Systems

DELIVERABLE No D.3.1
[External cost estimates database]

Due date of deliverable: 31st January 2007
Actual submission date: 17th March 2007

Start date of project: 1st April 2006 Duration: 30 months

Organisation name of lead contractor for this deliverable:
Institute for Environmental Studies (IVM), VU University of Amsterdam

Revision: FEEM

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

A Database of Studies on Energy-related External Costs due to Land Use Changes, Acidification and Eutrophication, Visual Intrusion and Climate Change

Onno Kuik[a]

Luke Brander[a]

Nataliya Nikitina[a]

Ståle Navrud[b]

Kristin Magnussen[b]

El Hadji Fall[c]

[a]Institute for Environmental Studies (IVM), VU University of Amsterdam

[b]SWECO, Norway

[c]Wageningen University, Environmental Economics and Natural Resources Group

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1 Introduction

This report presents an overview of recent literature on the external costs of energy-related impacts on land use change, acidification, eutrophication, visual intrusion and climate change across Europe and for selected non-EU countries. A brief description of the database is given for each of these areas.[1]

2 Land Use Changes

2.1 Introduction

This section presents an overview and list of economic studies related to the valuation of land use change and biodiversity loss. The purpose of this overview is to provide a basis for the transfer of existing value estimates for land use change and biodiversity loss to the impacts of air pollution on land use and biodiversity. The studies presented in this overview are therefore not necessarily on air pollution impacts per se, but assess the values of comparable environmental changes.

The list has been compiled from existing online databases of economic valuation studies (including the Environmental Valuation Reference Inventory – EVRI); economic journal databases; internet searches; and contact with researchers. In total we have identified 135 economic valuation studies relevant to this issue. The earliest study is from 1990 and the majority have been published since 2000. The current list is not exhaustive and we anticipate making further additions to the number of studies.

The content of this section is as follows: Section 1.2.2 describes the land use types assessed in the literature; Section 1.2.3 provides an overview of the location of valued sites; Section 1.2.4 examines the important environmental stressors that are addressed; and Section 1.2.5 presents the list of studies.

2.2 Land use types and biodiversity loss

The economic valuation literature addresses a broad range of changes to land use and biodiversity. Among the studies we have collected we have identified a number of specific land use categories that have been assessed in the literature. Table 1 presents the number of studies addressing each land use category. It is evident that some land use types are better represented than others, with forests being particularly well covered.

[1] The next paragraphs owe much to EEA (2006).

Table 1. Number of studies by land use type

Land use type	Number of studies
Agriculture	9
Forests	29
Rivers	4
Marine	2
Wilderness	3
Wetlands	10
Nature areas	4

A number of studies estimate values for biodiversity and species loss directly, without focusing on the associated habitat type. We collected ten studies that address biodiversity loss and four studies that examine impacts on species' populations. In addition, a few studies assess the impacts of invasive alien species on biodiversity.

2.3 Location of valuation sites

Economic valuation studies on land use change and biodiversity loss have been conducted in most parts of the world. Table 2 shows the number of studies from each continent. Close to half of all studies are for European sites. These studies are from a broad range of European countries, including the UK, France, Germany, Spain, Finland, Sweden, Greece, Denmark, Austria, Italy, and Iceland. In addition there are a number of studies that provide value estimates for multiple European countries or European regions, e.g. the Mediterranean and the Danube floodplain.

Land use change and biodiversity loss in North America is also well represented in the collected studies but there are fewer examples for other continents. A number of studies address land use change and biodiversity loss at a global scale.

Table 2. Number of studies by location

Location	Number of studies
Europe	63
N America	31
L America	7
Asia	9
Africa	3
Australasia	2
Global	12

2.4 Environmental stressors

As mentioned above, the environmental stressors underlying the land use change and biodiversity loss addressed in the collected studies includes, but are not restricted to, air pollution. Approximately ten studies deal specifically with air pollution impacts. Other environmental stressors that are commonly assessed include urban development and waste disposal.

2.5 List of economic valuation studies

Author	Year	Title	Publication
Adams R. et al.	1995	A Reassessment of the Economic Effects of Global Climate Change on U.S. Agriculture	Earth and Environmental Science
Adamson-Badilla M., Castillo F.	1998	Using Contingent Valuation to Estimate Prices for Non-Market Amenities Provided by Protected Areas	University of Costa -Rica
Adger, N.	1994	Towards Estimating Total Economic Value of Forests in Mexico	GEC 94-21, Centre for Social and Economic Research on the Global Environment, University of East Anglia and University College London
Alvarez-Fariz B. et al	1999	Estimating the benefits of Agri - environmental Policy: Econometric Issues in open-ended Contingent valuation Studies	Journal of Environmental Planning and Management
Alvarez-Farizo, B	2002	Using Conjoint Analysis to Quantify Public Preferences over the Environmental Impacts of Wind Farms. An Example From Spain	Energy Policy
Amann M, et al	2005	Baseline scenarios for the Clean Air For Europe (CAFE) programme	IIASA
Amigues Jean-Pierre	2002	The benefits and costs of riparian analysis habitat preservation: a willingness to accept/willingness to pay contingent valuation approach	Ecological Economics
Arin T,. Kramer R.	2002	Divers' willingness to pay to visit marine sanctuaries: an exploratory study	Oceans and Coastal Management
Atakelty, H.	2000	Complements, Substitutes, Budget Constraints and Valuation	Environmental and Resource Economics
Bandara R.	2005	Changing abundance of elephants and willingness to pay for their conservation	Journal of Environmental Management
Bann, C	1998	An Economic Analysis of Tropical Forest Land Use Options, Ratanakiri Province, Cambodia	Economy and Environment Program for Southeast Asia, International Development Research Center

Author	Year	Title	Publication
Banzhaf, S.	2004	Valuation of Natural Resource Improvements in the Adiron-dacks	Resources for the Future
Barbier E.	2000	Valuing the environment as input: review of applications to mangrove-fishery linkages	Ecological economics
Barbier, E.B.	1997	Economic Valuation of Wetlands: a Guide for Policy Makers and Planners	Ramsar convention Bureau
Barker, T., Knut R.	2002	Ancillary Benefits of GHG Mitigation in Europe: SO2, NOx, PM10 Reductions from Policies to Meet Kyoto Targets Using the E3ME Model and Externe Valuations	EU commission, Dir-Gen. XII for Science, Research and De-velopment
Basili,M.	2006	Analysing demand for environmental quality: A willingness to pay/accept study in the province of Siena (Italy)	Waste Management
Bastian C.	2002	Environmental amenities and agricultural land values: a hedonic model using geographic information systems data	Ecological Economics
Bergstrom J.	1990	Economic value of wetlands-based recreation	Ecological Economics
Berrens R.	1998	Exploring nonmarket values for the social impacts of environ-mental policy change	Recourses and energy economics
Beukering P. et al	2003	Economic valuation of the Leuser National Park on Sumatra, Indonesia	Ecological Economics
Biénabe E., Hearne R.R.	2006	Public preferences for biodiversity conservation and scenic beauty within a framework of environmental services payments	Forest policy and Economics
Birol, E	2005	Using a Choice Experiment to Estimate the Non-Use Values of Wetlands: The Case of Cheimaditida Wetland in Greece	Discussion Paper Series no. 08.2005, Environmental Economy and Policy Research, University of Cambridge
Boltz F.	2002	Shadow pricing diversity in US national forests	Journal of Forest Economics
Bonnieux F, Le Goff P	1997	Valuing the Benefits of Landscape Restoration: a Case Study of the Cotentin in Lower-Normandy, France	Journal of Environmental Management
Brander L. et al	2006	The recreational value of coral reefs: A meta-analysis	Ecological Economics

Author	Year	Title	Publication
Brink ten B.J.E.	2000	Technical Report on Biodiversity in Europe:an integrated economic and environmental assessment	RIVM , Bilthoven
Brouwer, R. and F. A. Spaninks	1999	The Validity of Environmental Benefits Transfer: Further Empirical Testing	Environmental and Resource Economics
Bulte, E. et al.	2002	Forest Conservation in Costa Rica when Nonuse Benefits are Uncertain but rising	American Journal of Agriculture Economics
Buttle, J.	2004	An Incremental Analysis of the Value of Expanding a Wilderness Area	Canadian Journal of Economics
Byström O.	2000	The Replacement Value of Wetlands in Sweden	Environment and Resource Economics
Carlsson F.	2003	Valuing weltands atributes: an application of Choice experiments	Ecological economics
Carlsson F.	2002	Willingness to pay for improved air quality in Sweden	Applied economics
CEEEP	2004	Economic Impact Analysis of New Jersey's Proposed 20% Renewable Portfolio Standard	The Center for Energy, Economic and Environmental Policy, The Edward J. Bloustein School of Planning and Public Policy State University of New Jersey
Champ P. et al	2005	Using contingent valuation to value a noxious weeds control program: the effects of including an unsure response category	Ecological economics
Colombo, S	2006	Analysing the social benefits of soil conservation measures using stated preference methods	Ecological Economics
Constanza R.	1997	The Value of the World's Ecosystem Services and Natural Capital	Nature
Cowichan Community Land Trust	2004	Ecological Strategies for the Cowichan Estuary	Report to the Ministry of Water, Land and Air Protection
Croitoru, L.	2006	How much are Mediterranean forests worth?	Forest Policy and Economics

Author	Year	Title	Publication
Curits I.	2004	Valuing ecosystem goods and services: a new approach using a surrogate market and the combination of a multiple criteria analysis and a Delphi panel to assign weights to the attributes	Ecological Economics
del Saz Salazar, S	2007	Estimating the Non-Market Benefits of an Urban Park: Does Proximity Matter?	Land Use Policy
Diakoulaki D.		Environmental externalities and the development of the renewable energy sources	Scholar google
Douglas J. Krieger. 2001.Benefit Transfer Over Time of Ecosystem Values. The Case of Forest Recreation.pdf	2001	Economic value of forest ecosystem services: A review.	Wilderness society
Drake L.	1999	The Swedish agriculturallandscape ± economic characteristics, valuations and policy options	International Journalof Social Economics
Dziegielewska, D	2005	Valuing Air Quality in Poland	Environmental and Resource Economics
Eade J.	1995	Spatial Economic Valuation: Benefits Transfer using Geographical Information Systems	Journal of environmental management
EFTE	2002	Populating the Environmental Valuation Reference Inventory: 40 European valuation studies	Final report submitted to European Commission, DG Environment by Economics for the Environment Consultancy Ltd
Elsasser P.	2005	Economic methodologies for valuing forest genetic resources	In: GEBUREK, T.; TUROK, J. (Hrsg.): Conservation and Management of Forest Genetic Resources in Europe. Zvolen: Arbora Publishers
Farber S.	2000	Using Conjoint Analysis To Value Ecosystem Change	Environmental Science and Technology
Font A.	2000	Mass Tourism and the Demand for Protected Natural Areas: A Travel Cost Approach	Journal of Environmental Economics and Management

Author	Year	Title	Publication
Garber-Yonts, B		Public Values for Biodiversity Conservation Policies in the Oregon Coast Range	Forest Science
Garrod G.	1992	The Amenity Value of Woodland in Great Britain: A Comparison of Economic Estimates	Environmental and Resource Economics
Garrod G. D.	1997	The non-use benefits of enhancing forest biodiveristy: a contingent ranking study	Ecological Economics
Geoghegan J.	1997	Spatial landscape indices in a hedonic framework: an ecological economics analysis using GIS	Ecological Economics
Georgiou, S.	2000	Contingent Ranking and Valuation of River Water Quality Improvements: Testing for Scope, Sensitivity, Ordering and Distance Decay Effects	CSERGE Working Paper GEC 2000-18,UK Economic and Social Research Centre
Gianni C.	2000	Willingness to pay for rural landscape preservation: a case study in Mediterranean agriculture	
Giraud K. L.	1999	Internal and external scope in willingness-to-pay estimates for threatened and endangered wildlife	Waste Management
Gren, Ing-Marie	1994	Economic Values of Danube Floodplains	Journal of environmental management
Groothuis, P.	1998	Using Contingent Valuation to Measure the Compensation Required to Gain Community Acceptance of a LULU: The Case of a Hazardous Waste Disposal Facility	Public Finance Review
Hanley N.	1998	Using Choice Experiments to Value the Environment	Environmental and Resource Economics
Hanson, T.R.	1995	Impact of Reservoir Water Level Changes on Lakefront Property and Recreational Values	Department of Agricultural Economics, Mississippi State University
Helfand G.	2006	The economics of native plants in residential landscape designs	Landscape and Urban Planning
Holland M.,		Benefits Table database:Estimates of the marginal external costs of air pollution in Europe, BeTa Version E1.02a	Created for European Commission DG Environment by netcen
Holland, M. et al.	1999	Economic Evaluation of Proposals for Emission Ceilings for Atmospheric Pollutants	Interim Report for DGXI of the European Commission

Author	Year	Title	Publication
Holmes T.	2004	Contingent valuation, net marginal benefits, and the scale of riparian ecosystem restoration	Ecological economics
Horne, P.	2003	Preferences for Alternative Moose Management Regimes among Finnish Landowners: A Choice Experiment Approach	Land Economics
Horne. P.	2005	Multiply-use management of forest recreational sites: A specially explicit choice experiment	Forest ecology and management
Horne. P.	2006	Forest owners Acceptance of insentive based policy instruments in Forest Biodiversity Conservation- A choice experiment based approach	Silva Fennica
Ihlanfeldta, K.	2004	Externality Effects of Small-Scale Hazardous Waste Sites: Evidence from Urban Commercial Property Markets	Journal of Environmental Economics and Management 47, 117-139
Jenkins D.	2002	Valuing high altitude spruce-fir forest improvements: importance of forest condition and recreation activity	Journal Forest Economics
Johnston R.	2001	Estimating amenity benefits of coastal farmland	Growth and change
Johnston R.	2003	Rural Amenity Values and Length of Residency	American Journal of Agricultural Economics
Klassen G.	2007	Internalizing externalities of electricity generation: An analysis with MESSAGE-MACRO	Energy Policy 35
Kniivilä M.	2002	Costs and benefits of forest conservation: regional and local comparisons in Eastern Finland	Journal of Forest Economics
Knut L. Seip	1991	Environmental impacts of energy facilities: fuel cell technology compared with coal and conventional gas technology	Journal of Power Sources,
Kontoleon A.	2003	The Willingness to Pay for Property Rights for the Giant Panda: Can a Charismatic Species Be an Instrument for Nature Conservation?	Land Economics
Koomey, J.	1990	Comparative analysis of monetary estimates of external environmental costs associated with combustion of fossil fuels	Report number LBL-28313

Author	Year	Title	Publication
Kosz M.	1996	Valuing riverside wetlands: the case of the "Donau-Auen" national park	Ecological Economics
Kramer R.	no year available	Contingent Valuation of Forest Ecosystem Protection	Forests in a Market Economy, Dordrecht, Nederlands 2002
Kreuter U.	2001	Change in ecosystem service values in the San Antonio area, Texas	Ecological economics
Krieger D.J.	2001	Benefit Transfer Over Time of Ecosystem Values: The Case of Forest Recreation	The wilderness society, Washington DC.
Kruger T.	2006	A Review of the Economic Benefits of Species and Habitat Conservation	Report
Kwak, S.	2003	Estimating the Public's Value for Urban Forest in the Seoul Metropolitan Area of Korea: A Contingent Valuation Study	Urban Studies
Ladenburg J.	2005	Economic valuation of the visual externalities of off-shore wind farms	Food and Resource Economic Institute
Lehtonen E.	2003	Non-market benefits of forest conservation in southern Finland	Waste Management
Leon, C. J.	1996	Double Bounded survival Values for Preserving the Landscape of Natural Parks	Journal of Environmental Management
Lienhoop N.	2007	Valuing wilderness in Iceland: Estimation of WTA and WTP using the market stall approach to contingent valuation	Land Use Policy
Loomis H.	2000	Measuring the total economic value of restoring ecosystem services in an impaired river basin: results from a contingent valuation survey	Ecological economics
Loomis J.	2000	Economic Values of Wilderness Recreation and Passive Use: What We Think We Know at the Beginning of the 21st Century	Scholar google
Markowska A.	1999	Costing an international public good: The case of the Baltic Sea.	Ecological Economics

Author	Year	Title	Publication
Mendonça M.	2003	A study on the valuing of biodiversity: the case of three endangered species in Brazil	Ecologocal economics
Mendonça, de, M.	2004	The economic cost of the use of fire in the Amazon	Ecological economics
Milon J. W.	2006	Latent preferences and valuation of wetland ecosystem restoration	Ecologocal economics
Mogas, J.	2002	A Comparison of Contingent Valuation and Choice Modelling: Estimating the Environmental Values of Catalonian Forests	National Centre for Development Studies,Australian National University, Canberra, Env. Management and Develop. Occasional Papers
Montgomery C.	1999	Pricing Biodiversity	Journal of Environmental Economics and management
Monzon A.	2004	Valuation of social and health effects of transport-related air pollution in Madrid (Spain)	Science of the Total Environment
Mourata S.	2000	Evaluating Health and environmental impacts of pesticide use: implication for the design of ecolabels and pesticide taxes	Environmental Science and Technology
Naidoo. R	2005	Biodiversity and nature-based tourismat forest reservs in Uganda	Environment and Development economics
Naylor, R	1998	Valuing Mangrove Resources in Kosrae, Micronesia	Environment and Development Economics
Ninan K.	2005	The economics of biodiversity conservation: a study of a cofee-region in the Western Ghats of India	Ecological Economics
Nunes P.	2001	Economic valuation of biodiversity: sence or nonsence?	Ecological Economics
Nunes P.	2003	Monetary Value Assessment of Clam Fishing Management Practices in the Venice Lagoon: Results from a Stated Choice Exercise.	Nota Di Lavoro 67.2003, Fondazine Eni Enrico Mattei
Nunes, P.	2004	Can People Value Protection against Invasive Marine Species? Evidence from a Joint TC-CV Survey in the Netherlands	Environment and Resource Economics
Olsson, Björn	2004	Two Essays on Valuation of Marine Resources: Applications to Sweden	Department of Economics Göteborg

Author	Year	Title	Publication
Pagiola S.	2004	Assessing the Economic Value of Ecosystem Conservation	The International Bank for Reconstruction and Development/THE WORLD BANK
Pearce D.	1994	The economic value of biodiveristy	The world conservation Union, Earthcan. London
Pearce D.	2001	The Economic Value of Forest Ecosystems	Ecosystem Health
Pouta E.	2004	Attitude and belief questions as a source of context effect in a contingent valuation survey	Journal of Economic Psychology
Powe N.	1997	Using a geographic information system to estimate an hedonic price model of the benefits of woodland access	Forestry
Pruncker G. J.	1995	Agricultural Landscape Cultivation in Austria: An application of the CVM	
Rafaj P.	2007	Internalisation of external cost in the power generation sector: Analysis with Global Multi-regional MARKAL model	Energy policy
Rehdanz, K.	2006	Hedonic Pricing of Climate Change Impacts to Households in Great Britain	Climat Change
Rehdanz,K.	2005	The Amenity Value of Climate to Households in Germany	Research Unit Sustainability and Global Change, Hamburg University and ZMA, Hamburg, Working Paper FNU-39 revised
Romer, A.	1998	Revealed Preferences for Reductions of Public Risks: An Application of the CV Approach	Journal of Environmental Planning and Management
Rozan, A.	2004	Benefit Transfer: A Comparison of WTP for Air Quality Between France and Germany	Environmental & Resource Economics
Ruijgrok E.	2004	Reducing Acidification: The Benefits of Increased Nature Quality. Investigating the Possibilities of the Contingent Valuation Method	The Fondazione Eni Enrico Mattei / NOTA DI LAVORO 65.2004
Shultz, S.	1990	The Willingness to Pay for Groundwater Protection	Water Resources Research

Author	Year	Title	Publication
Silberman, J.	1992	Estimating Existence Value for Users and Nonusers of New Jersey Beaches	Land Economics
Simpson R.	1996	Valuing Biodiversity for Use in Pharmaceutical Research	Journal of Political Economy
Sinden J.	2004	Estimating the opportunity costs of biodiversity protection in the Brigalow Belt, New South Wales	Journal of Environmental Management
Sundberg S.	2004	The economic value of environmental change in Sweden: A survey of studies	Welcome to ValueBaseSWE, http://www.beijer.kva.se/valuebase.htm
Swanson C.	1996	Roles of Nonmarket Economic Values in Benefit-Cost Analysis of Public Forest Management	United States Department of Agriculture, Forest Service, Pacific Northwest Research Station
Toivonen A.	2004	The economic value of recreational fisheries in Nordic countries	Fisheries Management and Ecology
Turner, R.	1999	Managing Nutrient Fluxes and Pollution in the Baltic: An Interdisciplinary Simulation Study	Ecological Economics
Turner, R.	2003	Valuing nature: lessons learned and future research directions	Ecological Economics
Turpie J.	2003	The existence value of biodiversity in South Africa: how interest, experience, knowledge, income and perceived level of threat influence local willingness to pay	Ecological Economics
Turpie J.	2003	Economic value of terrestrial and marine biodiversity in the Cape Floristic Region: implications for defining effective and socially optimal conservation strategies	Biological conservation
Tyrväinen L.	1996	The Amenity Value of Urban Forest; an Application of the Hedonic Pricing Method	Landscape and Urban Planning
Welsch, H	2003	Environment and Happiness: Valuation of Air Pollution in Ten European Countries	German Institute for Economic Research
White P.	1997	Economic values of threatened mammals in Britain: A case study of the otter Lutra lutra and the water vole Arvicola terrestris	Biological conservation

Author	Year	Title	Publication
Williams E.	2003	The value of Scotland's ecosystem services and natural capital	European Environment
Willis K.	2000	Non-market benefits of forestry	Centre for Research in Environmental Appraisal and Management University of Newcastle
Wood, L.	1995	How much are customers willing to pay for improvements in health and environmental quality	Electricity Journal
Woodward R. et al.	2001	The economic value of wetland services: a meta-analysis	Ecological Economics
Zandersen M. et al.	2005	Valuing New Forest Sites over Time: the Case of Afforestation and Recreation in Denmark	Research Unit Sustainability and Global Change (FNU), Hamburg University & Centre for Marine and Atmospheric Science (ZMAW), Germany
Zhongmin Xu	2003	Applying contingent valuation in China to measure the total economic value of restoring ecosystem services in Ejina region	Ecological Economics

3 Acidification of Terrestrial Ecosystems Including Agriculture

3.1 Introduction

The overall aim of this section is to review the studies valuing the benefits of terrestrial ecosystem recovery in monetary terms for acidification.

The effects of acidifying pollutants such as SO_2, NO_x and NH_3 on human health, crops and building materials have been the main external costs quantified in the literature.

The approach developed in this study is to review the main studies made for European countries in the line of the ExternE framework. There are some studies which consist on a review of the literature we do consider for the relevant information they contain for the methodology to value ecosystem. We also consider studies that contain information on critical loads. In particular, the report made by Hettelingh, Slootweg and Posch (2004) that describes the results of the call for data to produce an updated (2004) European database on critical loads and a novel European database on target loads. These databases are prepared for use in integrated assessment modelling exercises in support of European air pollution abatement policies.

The main approaches developed in the literature for valuation of acidification is the impact pathway approach and the contingent valuation method. Most of the studies in Europe uses the dose-response functions developed by the ExternE project, which is assessed by several authors as one of the most robust and consistent study in the subject.

The reliability of the science used varies considerably, in particular for the valuation based on contingent valuation method.

There is a lack of studies considering the dynamic aspects of ecosystem recovery for which the critical loads approach is weakly suitable to reduce scientific uncertainty, in particular for predictions.

Few authors point out the difficulties for temporal aggregation present with the long-term nature of ecosystem recovery. In general, discounting allows treating this problem, but for the time span at stake for recovery, e.g. hundred of years, the choice of discount rate is crucial.

3.2 Review of ecosystem valuation literature for acidification

The first study we analyze is the “Technical Report on Acidification, Eutrophication, and Tropospheric Ozone” made by **Cofala, Heyes, Klimont, Amann, Pearce, and Howarth** for RIVM in 2001.

The report compares the emissions of air pollutants and their environmental impacts for five emission scenarios. The scenarios have been created through a combination of assumptions about the development of emitting sectors and about the emission control policies in each of those sectors. Scenarios taken into consideration are: a Baseline (BL)

scenario, a Technology Driven (TD) scenario, an Accelerated Policy Scenario (AP), no climate change policies, i.e., mitigation of greenhouse gases emissions (AP_NC), an AP scenario with Kyoto targets of reduction of greenhouse gases emissions, no trade in emission rights (AP_NT) and an AP scenario with Kyoto targets, full trade in emission rights (AP_FT).

The assessment was done with the use of the IIASA integrated assessment model RAINS.

The report contains a description of the methodology of integrated assessment of air pollution control strategies used, the environmental indicators used in the assessment, a short characterization of the emission generating activities used. The emission scenarios and the assumptions made for constructing each of the scenarios, as well as the emissions, emission control costs and environmental indicators are discussed and compared.

Pollutants included are sulphur dioxide (SO_2), nitrogen oxides (NO_x), ammonia (NH_3) and non-methane volatile organic compounds (VOC). The baseline scenario simulates the effects of implementing current policies for the 'Business as Usual' scenario of economic development and energy consumption. The TD policy explores the implementation of all technical measures that are regarded as the best available control technologies in the EU member countries. The AP family of scenarios explores cost-efficient ways of achieving environmental targets for acidification and tropospheric ozone identical with those underlying the National Emission Ceilings Directive. Each of the AP scenarios demonstrates the effects of different policies with regard to climate change.

For the purpose of our study on valuation of acidification on terrestrial ecosystems including agriculture, we will concentrate on the part of this report which contains economic valuation of the benefits regarding acidification. The RIVM report contains benefit estimations of emission reduction measures for health impacts, material damage and crop impacts.

The unit damage values for SO_2, NO_x and NH_3 used in the study are drawn from a study of pan-European benefits from reductions in emissions (AEA Technology, 1999). These values are based on UNECE average values. The authors used the impact pathway approach to estimate the average damage values for the different pollutants.

Damage to human health, materials and agriculture are used for the calculation of the unit damage values needed for the benefit estimates for the acidification scenarios. Exposure response functions are used to quantify human health impacts, damage to materials and the effects of air pollution on agricultural systems.

According to the purpose of our study, we will present the exposure response functions used for agriculture only. The unit damage values used in the study include the four major impacts to agricultural systems: acidifying soils / liming; N deposition as fertiliser; direct effects of SO_2 and O_3 on crop yield and indirect SO_2 and O_3 effects on livestock.

The following functions are used to quantify the % yield change from SO_2 effects on different crops (maize, oats, leaf crops, soybeans, sunflower, barley, wheat, rice, millet, po-

tato, linseed, tomato, hops, tobacco, rye, sugar beet, beans, carrots, hemp, raspberries, cucumber, sorghum, strawberries, flax, and sesame seeds). These functions take into account the fertilisation effect of sulphur at low concentrations.

From 0 to 13.6 ppb SO_2: $\Delta = 0.74(SO_2) - 0.55(SO_2)^2$

Above 13.6 ppb SO_2: $\Delta = -0.69(SO_2) + 9.35$

For pasture the following exposure response functions are assumed:

From 0 to 15.3 ppb: $\Delta = 0.20(SO_2) - 0.013(SO_2)^2$

Above 15.3 ppb: $\Delta = -0.18(SO_2) + 2.75$.

For livestock the impacts of acidifying pollutants to meat and milk production are assumed to be 50% as sensitive to pasture grass.

Spash (1997) assesses the economic benefits to agriculture from air pollution control. His study is a review of the research in to the economic impacts of air pollution in agriculture crops for tropospheric ozone, acidic deposition and global climate change. The paper outlines the requirements for an economic assessment of crop loss moving from scientific monitoring to economic modelling. The problems related to the measurement of pollutants concentrations affecting crops and the approaches developed to assess the importance of air pollution for crop losses are described. Studies of crop loss due to acidic deposition are presented and problems of benefit assessment of this pollutant are identified by comparison with ozone. To avoid overlap analysis with the other studies of the project, we will concentrate on the part of the paper that deals with acidification problems. Before going through to the acidic deposition analysis of the study, we want to stress the parts on critical load and on the main assessment methods depicted by the author. The author notes that the critical load of SO_2 for indirect effects on agricultural crops is $30 \mu g m^{-3}$ with agricultural crops generally less sensitive than natural vegetation and forest. For direct effects on crops the critical load is equivalent to an annual mean pH of 3.0. Referring to Ashmore (1993), the critical load for direct effects on crops is unlikely to be exceeded anywhere in Europe.

The author has identified four main assessment methods of acid deposition damage to crop which are similar to the studies on ozone damage: the traditional model, linear and quadratic programming approaches, econometric approaches, and duality models. For traditional model, one can refer to Forster (1984) and Crocker (1985) for studies estimating welfare losses due to acid deposition on agriculture. Quadratic programming model is used by Adams, Hamilton and McCarl (1984, 1986) to calculate damages to U.S. agriculture. In a multi-regional study, Ludlow and Smit (1987) used a linear programming model for 17 crops and fruit to study acidic deposition damages in Ontario. Both experimental information and dose-response functions have been used for this study.

The main observation derived from the paper of Spach (1997) with respect to acidic deposition damages on crops are that the economic impacts estimated for U.S. are small compared to both other effects of acidic deposition (e.g. on forests, aquatic resources and materials) and to crop losses from ozone.

Christie et al. (2004) have developed measures for valuing changes in biodiversity on farmland using choice experiments and contingent valuation in the UK. Their approach was to apply the contingent valuation and choice experiment methods to valuing biodiversity on farmland, and its attributes. They use focus group to identify relevant attributes (such as rarity, endangered status, and familiarity), and to discover how best to overcome the lack of knowledge which most people have regarding what biodiversity is and why it matters. The choice experiment uses a fractional factorial design to combine characteristics of familiar species, endangered status, ecosystem functioning and cost. The contingent valuation study looks at habitat recreation and habitat improvement. They also investigate the extent to which workshop approaches to data collection can overcome some of the possible information problems in this instance, by testing out the effects of allowing for information exchange and group discussion on peoples' choices over biodiversity policy options.

The main conclusions the authors draw from their study are that the value people place on increases in biodiversity is positive, and significantly different from zero; people care about increasing biodiversity, but not how this is achieved, that the public do support policies that target rare familiar species of wildlife, but the evidence is less clear for the contribution that of common familiar species has, that there was evidence that the public would support policies that aimed to protect and enhance habitats, although the value of the implicit prices were found to be slightly lower than those found for the two species attributes.

Holland, Forster and King in their report "Cost-Benefit Analysis for the Protocol to Abate Acidification, Eutrophication and Ground Level Ozone in Europe" for AEA Technology in 1999 quantify the benefits of abatement in terms of both impacts (deaths brought forward, changes in crop yield, etc.) and their economic value. They compared the estimated costs of abatement directly to the benefits in a cost-benefit analysis (CBA). They use the Atmospheric Long-range Pollution Health/environment Assessment model to quantify the benefits in terms of reduced damage to health, materials and some aspects of managed ecosystems in agriculture and forestry. Costs and emissions are taken from the results of the RAINS model, dispersion calculations are based on EMEP, and databases on stock at risk (people, ecosystems, etc.) were supplied by RIVM. Exposure–response functions and valuation data have been taken from numerous sources, in particular the ExternE Project. Different scenarios have been analyzed to quantify the Protocol pollutants (SO_2, NO_x, VOC and NH_3) impacts on health, materials and crop yields. For the authors conclude that the list of benefits quantified is likely to exceed the costs of implementing all of the scenarios considered by a factor of between two and three. However, a number of effects, including those on ecosystems, remain outside the analysis because of limitations on the availability of data. The authors consider also that the estimated benefits are subject to significant uncertainties, meaning that there is potential for a broad range of possible outcomes in the results.

Hettelingh, Slootweg and Posch (2004) made a report for RIVM on "Critical Loads and Dynamic Modelling Results". As the authors defined it critical loads are thresholds of

air polluting compounds which should not be exceeded to protect ecosystems from risk of damage, e.g., from acidification and eutrophication and dynamic modelling data provide information on the future time required to have an ecosystem recover from such a risk, whenever critical loads are no longer exceeded. This report describes the results of the call for data to produce an updated (2004) European database on critical loads and a novel European database on target loads. These databases are prepared for use in integrated assessment modelling exercises in support of European air pollution abatement policies. The report contains the updated data submitted by sixteen European countries on critical loads of acidity and of nutrient nitrogen. Eleven countries also submitted the requested dynamic modelling results. The comparison of ecosystem specific deposition to the 2004 critical loads leads to a larger area of unprotected ecosystems than that computed in the past. It is shown that ecosystems which are unprotected against acidification and eutrophication in 2000 cover 11% and 35% of the European ecosystem area, respectively. The report contains also the national reports made by the countries that participate to the call for data.

The critical loads analyzed consist of four variables which were used to support the Gothenburg Protocol. These variables are the basis for the maps used in the effect modules of the European integrated assessment modelling effort: (a) the maximum allowable deposition of S, i.e. the highest deposition of S which does not lead to 'harmful effects' in the case of zero nitrogen deposition, (b) the minimum critical load of nitrogen to ensure sufficient nitrogen for plant uptake including nitrogen immobilisation (c) the maximum 'harmless' acidifying deposition of N in the case of zero sulphur deposition, and (d) the critical load of nutrient N preventing eutrophication of ecosystems. The critical loads exceedances have been computed as the 'average accumulated exceedance' by using critical loads of acidity in integrated assessment modelling to support the analysis of emission reduction alternatives.

Otterström, Hämekoski and Anton (2003) make a report on the "Estimation of environmental costs of aircraft LTO emissions" for Electrowatt-Ekono. They use the ExternE methodology to estimate the marginal environmental emission costs of aviation. The marginal emission costs caused by one aircraft type have been assessed at Västerås airport. The emission inventory consists of the emissions caused by the case aircraft. Dispersion modelling calculations are performed for an LTO cycle at Västerås airport. The authors consider six pollutants in their calculations: nitrogen oxides (NO_x and NO_2), carbon monoxide (CO), hydrocarbons (HC), particulate matter (PM), and sulphur dioxide (SO_2). In addition, ozone (O_3) depletion due to the chemical transformation of nitrogen oxides was computed.

The impacts include mortality and morbidity, impacts on building materials and crops, and global warming. Information for the valuation of impacts is based on research results mainly from ExternE, UNITE and the BeTa database of the European Commission. The results indicate that impacts related to global warming form the main cost category covering approximately 79 - 84% of the total costs when the assessment is based on a shadow value of EUR 65/t CO_2. The variation depends on whether UNITE or BeTa input

data for regional impacts is used. The cost of regional impacts contributes 11 – 21% to the total costs and local impacts by approximately 5%. The total costs are EUR 130 - 137 per LTO cycle. The authors noticed that uncertainties of the results of their study concern primarily the credibility of the exposure-response functions and their application in the case areas, the data on particulate emissions, and the appropriateness of the unit costs used for assessing the costs of health, crop, and material impacts in Sweden. The direct impacts of SO_2, NO_x, NH_3 and VOC and related secondary pollutants on health, building materials and crops have been estimated and quantified as well as valued in money. However, for the authors the impacts of acidification on ecosystems can not be quantified in a way which would support monetary valuation. The impacts of acid deposition of soils of managed agricultural systems (effects of fertilisation, ground disturbance, and harvest) have been counteracted with liming.

The authors pointed out a published study of Naturvårdsverket (Naturvårdsverket, 2002) on acidification in Sweden. They noticed that according to the study the critical load for acidification and eutrophication is exceeded on a 2 – 3 times larger area than estimated earlier with a courser modelling grid. The areas in question are primarily surface waters and forest area soils. The analysis shows that the exceedance area with respect to critical load for acidification has diminished from 60% in 1980 to 41% in 1990 and further to 22% in 1997. Assuming that European emissions of sulphur and nitrogen emissions are reduced in accordance with the Göteborg Protocol, the critical load will still be exceeded on 13% of Sweden, equalling to 5.1 million hectares. The estimates given provide an overview of the current state of the deposition compared with critical loads. They do not, however, provide information on the actual state of the environment.

Ruijgrok (2004) developed a contingent valuation method to investigate the benefits of increased nature quality by reducing acidification. The study has been aimed to show that CVM can be used to estimate two specific benefits of increased nature quality due to acidification abatement: the non-use value and the recreational perception value. A CVM questionnaire was designed to determine the difference between the welfare generation of healthy ecosystems not suffering from acidification and unhealthy ecosystems affected by acidification. The results of the pre test suggest that the benefits of nature may be quite large and that they should therefore not be overlooked. The author sets up a CVM-survey to determine the non-use value of increased nature quality (i.e. increased biodiversity and vitality) due to acidification abatement. The study contains also a CVM-survey to determine the recreational perception value of increased nature quality.

The author find that the willingness to pay for non-use values varied from Euro 0 to Euro 100 per household per year. The average was Euro 30 per household per year. Multiplied with the 6.9 million households of the Netherlands, this results in a first rough estimate of Euro 207 million per year. This rough impression of the expected magnitude of the nature benefits of acidification abatement in the Netherlands is an indication that the benefits of increased nature quality due to acidification abatement are worth taking into account for the author.

Vermoote and De Nocker (2003) proposed a standard-price approach to value the environmental impacts of acidification and eutrophication, i.e. to use the abatement costs of emissions reductions as a proxy for the revealed willingness to pay of European society for the improvements in ecosystems health. Different to the valuation approach used in ExternE, which reflects WTP of individual, their approach is meant to estimate the revealed preferences of policy makers. It calculates the benefits of emission reduction – as perceived by policy makers - based on the abatement costs to reach a well-defined emission reduction target. The authors analysis combines the impact pathway approach to estimate impacts in physical terms, which are then valued following an analysis of international agreements of emission reductions in Europe so that they can estimate the shadow price per tonne of emissions. The authors consider the number of hectares of ecosystem, for which critical loads for acidification and eutrophication have been exceeded, as the physical indicator to valuate the effects of acidification and eutrophication on ecosystems. Exceedances of different types of ecosystems, both terrestrial and aquatic, have been added up. They have evaluated the number of hectares of ecosystem for which the critical loads are exceeded for the whole of the EU15, non-EU and Europe.

For the costs indicators, they assume that the costs as estimated by the technical-economic models are a good indicator for the WTP. The average costs of a marginal policy package have been considered.

Three scenarios have been considered in their study: a reference scenario, a NEC scenario considering the UN-ECE Gothenburg protocol and the EU directive, and a "NECi" scenario for the initial NEC proposal.

As results of Vermoote and De Nocker (2003) study, we can point out that the WTP per hectare varies from 63 to 350 €/hectares of ecosystems protected in Europe and for EU-15 from 338 to 674 €/ha. The external costs estimated reveals that they are varying significantly, ranging from 4 to 637 € per tonne SO_2 and from 167 to 1.661 € per tonne NO_x (in year 2000). In general, impacts and shadow prices are low for emissions from countries at the edge and South of Europe, whereas the impacts are relative very high for emissions from the Scandinavian countries, Denmark, Sweden and Finland. On average, and for most countries, the shadow price for NO_x is higher due to the fact that it contributes to both acidification and eutrophication.

The limits noticed by the authors for their study concern the lack of the 'dynamic' aspect of the critical loads concept, the fact that they use the number of hectares of ecosystem for which the critical loads are exceeded to express the exceedance of critical loads in their determination of the WTP. The exceedance of critical loads can also be expressed in terms of total accumulated exceedance of critical loads (expressed in equivalents deposition per year) or the average accumulated exceedance (expressed in terms of equivalents deposition/ha*year). These last measures have the advantage that they vary smoothly when depositions vary and thus they are not vulnerable for discontinuous distributions of the critical loads in a grid cell.

Howarth et al. (2001) investigate the benefits of environmental policy for the Netherlands. The report focuses on seven environmental issues including: climate change, acidification, low level ozone, particulate matter, noise, eutrophication and land contamination. The damage assessment approach follows the impact pathway approach, e.g. emission, change in exposure, quantification of impacts using exposure-response functions and valuation based on willingness to pay. Unit damage values for the acidifying pollutants (SO_2, NO_x and NH_3) have been based on the ExternE report (1997) for the Netherlands with some adjustments. Damages to the Netherlands due to acidifying pollutants from Holland and elsewhere have been calculated.

Bouwman and van Vuuren (1999) also made a report for RIVM on "Global assessment of acidification and eutrophication of natural systems". The report contains a global assessment of the present and possible future acidification and eutrophication risks of natural and semi-natural terrestrial ecosystems, and riverine nitrogen transport to estuaries, coastal seas and continental shelves. The main objective of their study was to estimate the areas potentially affected by deposition of nitrogen and sulphur compounds and the severity of acidification and eutrophication problems. As results, they indicate that the critical loads for acidification and eutrophication are exceeded in 6-15% and 7-18% of the global area of natural and semi-natural ecosystems, respectively.

The following table summarizes the studies reviewed in this report.

Study	Countries /regions	Types of publication	Functions /resources valued	dates	Valuation approaches
Cofala et al.	EU-15 and Europe	report	Benefit estimates of SO_2, NO_x, and NH_3 emission reductions to human health, materials damage and agriculture impacts	2001	Impact pathway
Spash	USA/ Europe	Article/survey		1997	
Christie and al.	UK	article	Valuing biodiversity	2004	Contingent valuation and choice experiment

Study	Countries /regions	Types of publication	Functions /resources valued	dates	Valuation approaches
Holland et al.	Europe	report	Acidifying pollutants (SO_2, NO_x, VOC and NH_3) impacts on health, materials and crop yields	1999	Impact pathway approach
RIVM	Europe	report	Critical loads	2004	Impact pathway approach
Otterström et al.	Sweden	report	nitrogen oxides, carbon monoxide, hydrocarbons, particulate matter, and sulphur dioxide	2003	Impact pathway approach
Ruijgrok	Netherlands	Working paper	benefits of increased nature quality by reducing acidification	2004	Contingent valuation
Vermoote and De Nocker	EU-15 and Europe	article	Valuation of environmental impacts of acidification and eutrophication : SO_2, NO_x, and NH_3	2003	Standard price approach
Howarth et al.	Netherlands	report	Valuation of the benefits of environmental policy (in particular, acidification impacts on agriculture, health and materials)	2001	Impact pathway approach
Bouwman and van Vuuren	World	report	Acidification and eutrophication	1999	

3.3 Conclusion

Valuing acidification on terrestrial ecosystem is a difficult exercise due to scientific uncertainty about the impact of abatement on ecosystem recovery and the challenges of valuing long term and complex environmental changes.

However, research should continue to try to apply the damage function approach for impacts on ecosystems. To this purpose, the ecosystem functions approach needs to be further explored, building further on the results of the available studies (cf. report of the UN-ECE workshop, 2003).

We believe that appropriately planned valuation research conducted in collaboration with scientific experts would yield reliable benefit estimates that would be useful for policy purposes.

The uncertainties concerning monetary valuation should not be understated and benefit estimates must be considered to be conservative, lower bound estimates of total ecosystem value.

3.4 Extensive literature related to the topics not described

Alan J., Krupnick, A.J. and Burtraw, D. (1996) The Social Costs of Electricity: Do the Numbers Add Up? Discussion Paper 96-30. Resources for the Future, Washington DC.

Banzhaf, P., Burtraw, D., Evans, D., and Krupnick, A. (2004) Valuation of Natural Resource Improvements in the Adirondacks. Resource For the Future, Washington DC.

Bateman, I.J., Cooper, P., Georgiou, S., Navrud, S., Poe, G.L., Ready, R., Riera, P., Ryan, M., Vossler, C.A. (2003) Scope sensitivity tests for preference robustness: an empirical examination of economic expectations regarding the economic valuation of policies for reducing acidity in remote mountain lakes. CSERGE Working Paper EDM 04-03.

Callaway, J. M., Darwin, R. F., Nesse, R. J. (1986) Economic valuation of acidic deposition damages: Preliminary results from the 1985 NAPAP Assessment. *Water, Air, and Soil Pollution*, vol.31, pp. 1019-1034.

Eshet, T., Ayalon, O. and Shechter, M. (2005) A critical review of economic valuation studies of externalities from incineration and land filling, *Waste Management & Research*; vol. 23, pp. 487-504.

Hanley, N., Spash, C. and Walker, L. (1995) Problems in Valuing the Benefits of Biodiversity Protection. *Environmental and Resource Economics*, vol. 5, pp. 249-272.

Krewitt, W. (2002) External costs of energy- do the answers match the questions?

Looking back at 10 years of ExternE. *Energy Policy*, vol. 30, pp. 839–848.

MacMillan, D. (2001) Valuation of Air Pollution Effects on Ecosystems: A Scoping Study. Report DEFRA, UK.

MacMillan, D.C., Duff, E.I. and Elston, D.A. (2001) Modelling the Non-market Environmental Costs and Benefits of Biodiversity Projects Using Contingent Valuation Data. *Environmental and Resource Economics*, vol.18, pp.391–410.

Mullen, J.K. and Menz, F.C. (1985) The Effect of Acidification Damages on the Economic Value of the Adirondack Fishery to New York Anglers. *American Journal of Agricultural Economics*, Vol. 67, No. 1. (Feb., 1985), pp. 112-119.

NewExt (2004) New Elements for the Assessment of External Costs from Energy Technologies. Publishable Report to the European Commission, DG Research, Technological Development and Demonstration.

Olsthoorn, H., Amann, M., Bartonova, A., Clench-Aas, J., Cofala, J., Dorland, K, Guerreiro, C., Henriksen, J.F., Jansen, H. and Larssen, S. (1999) Cost Benefit Analysis of European Air Quality Targets for Sulphur Dioxide, Nitrogen Dioxide and Fine and Suspended Particulate Matter in Cities. *Environmental and Resource Economics*, vol.14, pp.333–351.

Pearce, D. (2001) Energy Policy and Externalities: An Overview. Paper prepared for OECD Nuclear Energy Agency.

Torfs, R., De Nocker, L. and Panis, L.I. (2001) The introduction of renewable to reduce externalities of power production. Vito, Integrated Environmental Studies.

Willis, K., Garrod, G., Scarpa, R., Macmillan, D. and Bateman, I. (2000) Non-Market benefits of forestry. Report for Forestry Commission, Centre for Research in Environmental Appraisal and Management. UK.

4 Visual Intrusion by Wind and Hydro

We collected a number of Nordic studies on visual intrusion of wind and hydro from the EVRI database. A small part of the database is presented below. Additional entries in the database include fairly extensive descriptions of the objectives of study, the study site, the specific object of valuation, the valuation method, etc. In total the database contains 102 columns (which are not necessarily filled in for each study). The collection is not yet complete; obviously data from other parts of Europe have to be added.

Visual Intrusion by Wind and Hydro

Title	Authors	Source_t	Doc_Type	Ref_Date
"Samfundsmæssig værdi af vindkraft. Delrapport: Visuelle effekter og støj fra vindmøller - kvantificering og værdisætning." (Social Costs of Wind Power: Partial Report of Visual Impacts and Noise from Windmills).	Jordal-Jørgensen, J.	Institute for Local Government Studies (AKF), Copenhagen, Denmark 1995	report (government/non-government)	December 1, 1995

Title	Authors	Source_t	Doc_Type	Ref_Date
"Environmental Costs of Hydropower, Second Stage – Miljøkostnadsprosjektet Trinn 2."	Navrud S.	EBL report 181- 2004.	report (government/non-government)	July 1, 2004
"Quantifying Household Preferences over the Environmental Impacts of Hydropower in Sweden: A Choice Experiment Approach"	Sundqvist, T.	Dissertation, 2002:26, Luleå University of Technology, Sweden.	dissertation/thesis	August 1, 2002
"Environmental Effects of Windmills in Sandøy, a Contingent Valuation Study - Miljøkonsekvenser av vindkraft i Sandøy kommune, en verdsettingsstudie"	Gjøsund, H. C. S.	Norwegian University of Life Sciences (UMB)	dissertation/thesis	May 1, 2003
"A Contingent Valuation Study of Environmental Impacts of Windmill Development of Smøla - Miljøkostnader av vindkraftutbygging på Smøla"	Nordahl, E.	Norwegian University of Life Sciences (UMB)	dissertation/thesis	August 1, 2000
"Valuing Aesthetical Values of Weirs in Watercourses with Hydroelectric Plants - Verdsetjing av estetiske verdiar i tilknytning til tersklar i regulerte vassdrag"	Bergland, O.	Norwegian Water Resources and Energy Directorate (NVE)	report (government/non-government)	May 1, 1998
"Environmental Accounting for Wind Energy - Miljøregnskap for vindkraft"	Axelsen, L.K.	Norwegian University of Life Sciences (UMB)	dissertation/thesis	August 1, 2003
"Environmental Costs of Hydropower Development - Estimering av miljøkostnader ved en vannkraftutbygging i Øvre Otta"	Hansesveen, H. and G. Helgås	Norwegian University of Life Sciences (UMB)	dissertation/thesis	May 1, 1997
"Environmental Costs due to the Kárahnjúkar Hydro Power Project on Iceland"	Bothe, D.	University of Cologne	working paper	June 1, 2003
"Economic Valuation of the Visual Externalities of Offshore Wind Farms"	Ladenburg, J., A. Dubgaard, L. Martinsen and J. Tranberg	Food and Resource Economic Institute	report (government/non-government)	January 1, 2005

Title	Authors	Source_t	Doc_Type	Ref_Date
"Documentation of Three Contingent Valuation Surveys on Preservation of Landscape Elements of Agricultural Land"	Hasund, K.P.	Småskriftserien no 107, Swedish University of Agricultural Sciences (SLU), Department of Economics, Uppsala.	report (government/non-government)	January 1, 1997
"Valuing the Environmental Impacts of Wind Power: A Choice Experiment Approach"	Ek, K.	Thesis, Lulea University of Technology	dissertation/thesis	January 1, 2002
"Implicit Environmental Costs in Hydroelectric Development: An Analysis of the Norwegian Master Plan for Water Resources"	Carlsen, A.J., J. Strand, and F. Wenstop	Journal of Environmental Economics and Management 25, no. 3, 201-211	journal	November 1, 1993

5 Acidification and Eutrophication of the Marine Environment

We collected a number of Nordic studies on acidification and eutrophication from the EVRI database. A small part of the database is presented below. Additional entries in the database include fairly extensive descriptions of the objectives of study, the study site, the specific object of valuation, the valuation method, etc. In total the database contains 102 columns (which are not necessarily filled in for each study). The collection is not yet complete; obviously data from other parts of Europe have to be added.

Acidification

Title	Authors	Source_t	Doc_Type	Ref_Date
"The Economic Value of Recreational Fisheries in Nordic Countries"	Toivonen, A.L., E. Roth, S. Navrud, G. Gudbergsson, H. Appelblad, B.Bengtsson, and P.Tuunainen.	Fisheries Management and Ecology 11, pp. 1-14.	journal	January 1, 2004
"Socio-economic Efficiency of Liming Lake Vegår - Samfunnsøkonomisk lønnsomhet av å kalke Vegår"	Navrud, S.	Directorate for Nature Management (DN)	report (government/non-government)	July 1, 1993

Title	Authors	Source_t	Doc_Type	Ref_Date
"Socio-economic Efficiency of Liming Lake Vegår - Samfunnsøkonomisk lønnsomhet av å kalke Vegår"	Navrud, S.	Directorate for Nature Management (DN)	report (government/non-government)	July 1, 1993
"The Recreational Value of Sports Fishing for Salmon in Drammenselva - Rekreasjonsverdien av fritidsfisk etter laks i Drammenselva"	Aae. R.	Norwegian University of Life Sciences (UMB)	dissertation/thesis	June 1, 1995
"The Recreational Value of Sports Fishing in Dokka/Etna for the 1993/1994 Season - Rekreasjonsverdien av fisket i Dokka/Etna for 1993- og 1994-sesongen"	Pedersen, H.	Norwegian University of Life Sciences (UMB)	dissertation/thesis	May 1, 1995
"The Recreational Value of Sports Fishing in Dokka/Etna for the 1993/1994 Season - Rekreasjonsverdien av fisket i Dokka/Etna for 1993- og 1994-sesongen"	Pedersen, H.	Norwegian University of Life Sciences (UMB)	dissertation/thesis	May 1, 1995
"The Recreational Value of Trout Sports Fishing in Dokkavassdraget - Rekreasjonsverdien av fritidsfisket etter ørret i øvre deler av Dokkavassdraget og holdninger til fiskestelltiltak"	Nielsen, F.S. and L.I. Vestby	Norwegian University of Life Sciences (UMB)	dissertation/thesis	May 1, 1995
"Linking Physical and Economic Indicators of Environmental Damages"	Navrud, S.	Chapter 6 in C. L. Spash and S. McNally (eds.) 2001: Case Studies in Ecological and Environmental Economics. John Wiley & Sons Ltd.	chapter in book	January 1, 2001

Title	Authors	Source_t	Doc_Type	Ref_Date
"Linking Physical and Economic Indicators of Environmental Damages"	Navrud, S.	Chapter 6 in C. L. Spash and S. McNally (eds.) 2001: Case Studies in Ecological and Environmental Economics. John Wiley & Sons Ltd.	chapter in book	January 1, 2001

Eutrophication

Title	Authors	Source_t	Doc_Type	Ref_Date
"Contingent Valuation of a Less Eutrophicated Baltic Sea"	Soderquist, T.	Beijer Discussion Paper Series No. 88 Beijer International Institute of Ecological Economics, The Royal Academy of Sciences, Stockholm.ISSN 1102-4941	working paper	January 1, 1996
Evaluation des beneficies lies a al realisation dúne reserve d'eau potable a partir de l'Erde et evaluation des beneficeies touristique lies a l'amelioration de la qualite de l'eau de l'Erde	Brunel, A.	Universite des Sciences Sociales, Toulouse I Memoire de DEA	dissertation/thesis	December, 1996
"Managing Nutrient Fluxes and Pollution in the Baltic: An Interdisciplinary Simulation Study"	Turner, R.K., S. Georgiou, I-M. Gren, F. Wulff, S. Barrett, T. Soderqvist, I.J. Bateman, C. Folke, S. Langaas, T. Zylicz, K-G. Maler, and A. Markowska	Ecological Economics 30: 333-352	journal	January 1, 1999

Title	Authors	Source_t	Doc_Type	Ref_Date
"Managing Nutrient Fluxes and Pollution in the Baltic: An Interdisciplinary Simulation Study"	Turner, R.K., S. Georgiou, I-M. Gren, F. Wulff, S. Barrett, T. Soderqvist, I.J. Bateman, C. Folke, S. Langaas, T. Zylicz, K-G. Maler, and A. Markowska	Ecological Economics 30: 333-352	journal	January 1, 1999
"The Economic Value of Recreational Fisheries in Nordic Countries"	Toivonen, A.L., E. Roth, S. Navrud, G. Gudbergsson, H. Appelblad, B.Bengtsson, and P.Tuunainen.	Fisheries Management and Ecology 11, pp. 1-14.	journal	January 1, 2004
"Elasticities of Demand and Willingness to Pay for Environmental Services in Sweden"	Hokby, S. and T. Soderqvist.	Environmental and Resource Economics 26, 361-383	journal	January 1, 2003
"Costing an International Public Good: The Case of the Baltic Sea"	Markowska, A. and T. Zylicx	Ecological Economics 30, 301-316.	journal	January 1, 1999
"The Regional Willingness to Pay for a Reduced Eutrophication in the Stockholm Archipelago"	Soderqvist, T. and H. Scharin	Discussion paper no. 128, Beijer International Institute of Ecological Economics, The Royal Swedish Academy of Sciences.	working paper	January 1, 2000
"An Initial Economic Evaluation of Water Quality Improvements in the Randers Fjord, Denmark"	Atkins, J.P. and D. Burdon	Marine Pollution Bulletin, article in press	journal	January 1, 2005

Title	Authors	Source_t	Doc_Type	Ref_Date
"Transfer of Benefit Estimates: The State of Norway, and Tests of Water Quality- Overføring av nytte-estimater: Status i Norge og utprøving knyttet til vannkvalitet. Del II Utprøving knyttet til vannkvalitet" (original report is in Norwegian only)	Magussen K.,O. Bergland and S. Navrud.	NIVA - Norwegian Institute for Water Research (Norsk institutt for vannforskning)	report (government/non-government)	November 1, 1995
"Halved Emissions of Nutrients, What are the Benefits? - A Contingent Valuation Method Survey Applied to Laholm Bay"	Frykblom, P.	Doctor's dissertation, Swedish University of Agricultural Sciences, Uppsala.	dissertation/thesis	May 1, 1998
"Valuation of Reduced Pollution to the North Sea - Verdsetting av redusert forurensing til Nordsjøen"	Magnussen, K. and S. Navrud	Norwegian Agricultural Economics Research Institute (NILF)	report (government/non-government)	March 1, 1992
"Willingness to Pay for Improved Water Quality of Steinsfjorden - Betalingsvillighet for en bedret vannkvalitet i Steinsfjorden"	Lindhjem, H.	The University of Oslo (UiO)	dissertation/thesis	May 1, 1998
"The Recreational Value of Sports Fishing in Dokka/Etna for the 1993/1994 Season - Rekreasjonsverdien av fisket i Dokka/Etna for 1993- og 1994-sesongen"	Pedersen, H.	Norwegian University of Life Sciences (UMB)	dissertation/thesis	May 1, 1995
"The Recreational Value of Trout Sports Fishing in Dokkavassdraget - Rekreasjonsverdien av fritidsfisket etter ørret i øvre deler av Dokkavassdraget og holdninger til fiskestelltiltak"	Nielsen, F.S. and L.I. Vestby	Norwegian University of Life Sciences (UMB)	dissertation/thesis	May 1, 1995

Title	Authors	Source_t	Doc_Type	Ref_Date
"The Value of Improved Water Quality - A Random Utility Model of Recreation in the Stockholm Archipelago"	Soutukorva, Å	Beijer Discussion Paper Series No. 135, Beijer International Institute of Ecological Economics, The Royal Swedish Academy of Sciences.	working paper	May 1, 2005
"Heterogenous preferences for marine amenities: A choice experiment applied to water quality"	Eggert, H. and B. Olsson	Licentiate thesis, Department of Economics, School of Economics and Commercial Law, Göteborg University.	dissertation/thesis	April 1, 2004
"Alternative Nitrogen Reduction Policies in the Mälar Region, Sweden"	Gren, I-M.	Ecological Economics, 7, pp. 159-172.	journal	January 1, 1993
"Valuing Environmental Benefits Using the Contingent Valuation Method" (Ympäristöhyötyjen arviointi contingent valuation -menetelmällä)	Mäntymaa E.	Research Reports 109, Research Institute of Northern Finland, University of Oulu.	report (government/non-government)	January 1, 1993
"Valuing Environmental Benefits Using the Contingent Valuation Method" (Ympäristöhyötyjen arviointi contingent valuation -menetelmällä)	Mäntymaa E.	Research Reports 109, Research Institute of Northern Finland, University of Oulu.	report (government/non-government)	January 1, 1993
"Valuing Environmental Benefits Using the Contingent Valuation Method" (Ympäristöhyötyjen arviointi contingent valuation -menetelmällä)	Mäntymaa E.	Research Reports 109, Research Institute of Northern Finland, University of Oulu.	report (government/non-government)	January 1, 1993

Title	Authors	Source_t	Doc_Type	Ref_Date
"Recreational Benefits from Improved Water Quality: A Random Utility Model of Swedish Seaside Recreation"	Sandstrom, M.	Stockholm School of Economics, Economics Research Institute, Working Paper No. 121	working paper	August 1, 1996

6 Climate change

At present, more than one hundred estimates of the marginal external costs of the emissions of greenhouse gases (particularly CO2) have been made. The estimates range from slightly negative (< 0) to over 400 USD per ton CO2 currently emitted. Tol (2005) constructed a probability density function of published estimates. The function is highly skewed to the left, with a long right tail of sparse but high estimates. The mean value of the published estimates is 25 USD per ton of CO2, but 50% of the studies report costs of less than 4 USD/ton (this is the median value). On the other extreme, 5% of the studies report costs of over 95 USD/ton. If only peer-reviewed studies are taken into account, the mean estimate drops to 12 USD/ton with a standard deviation of 23 USD/ton.

Most researchers agree that the marginal impacts of greenhouse gas emissions increase with the concentration of greenhouse gases in the atmosphere. Therefore, it is commonly assumed that because of the expected increases in concentration over time, the present value of emissions also increases over time. That is, all else being equal, the present value of emissions in 2010 will be higher than the present value of emissions in the year 2000. The literature reports annual increases in the marginal costs of CO_2 emissions range between 1 and 2 percent. Annual increases of marginal costs for other greenhouse gases may differ in relation to their expected lifetime in the atmosphere. The qualifier “all else being equal” used above primarily relates to the vulnerability of natural and economic systems and their ability to adapt to a changing climate.

Recently, there has been a flurry of research projects on the ‘social cost of carbon’ (SCC) in the United Kingdom. The social cost of carbon is the social cost of the emission of one tonne of CO2 at a particular date; hence it is another word for the marginal (social) cost of CO2 emissions. It is measured as the present value of the impacts of one tonne of CO2 over its lifetime in the atmosphere.

Large-scale projects included the SCC-project of Watkiss, Downing and others and, most recently, the Stern Review. The specific objectives of the SCC project were to review the previous use of the SCC values in policy assessment, and the possible approaches for future assessment, taking into account the factors that influence the values; to undertake expert stakeholder consultation, to obtain their views on how such analysis should be undertaken, and on the uses of SCC estimates in policy assessment in the face

of uncertainty; to develop a series of case studies to demonstrate the various approaches for including SCC estimates in policy decision-making; and to make recommendations. The study reviewed the key policy choices on parameters that affect the SCC, finding that much of the variation in SCC estimates (for the sub-totals assessed so far) arise from a few key parameters in the choice of decision perspectives, most importantly the discount rate used and the approach to weighting impacts in different regions (called equity weighting). Potential approaches for using the SCC values in policy applications that take risk and uncertainty into account were reviewed, identifying a number of options (such as the use of an illustrative central value, the use of a range, switching values, sequential sensitivity analysis, different values for different applications, marginal abatement costs, multi-criteria analysis, other risk analysis techniques).

The project also produced new estimates of the SCC, most notably through upgrading the FUND2 model (with new work on health, tourism, catastrophic events, collapse of the Thermohaline Circulation, high climate sensitivities, large methane releases) to allow full testing of parameter uncertainties. The project developed a risk matrix of uncertainty in climate forcing and economic valuation of impacts. The study suggests that no single method, model or tool adequately captures all of the uncertainties. The complexity of the nature of a coupled socio-ecological system (climate change is driven in part by its impacts over time) and the range of decision frameworks that might be employed in using the SCC imply that estimates of the SCC will remain diverse and contentious. That is, there is little consensus regarding the central value that should be adopted and relatively little confidence in the reliability of the evidence available upon which SCC estimates can be made.

The review argues that "using typical assumptions about discounting and aggregation", some central estimates of the marginal damage cost of carbon dioxide emissions may be lower than the "illustrative value" of £70/tC (€28/tCO_2) that is currently used by the UK government. This reflects a trend in the literature towards lower SCC values in recent years. However, the literature studies do not cover all the impact categories of climate change, and most researchers consider the possibility of negative surprises to be more likely than positive ones. The authors therefore assessed the coverage of the valuation studies to investigate the extent to which they may under-estimate the total SCC. The studies were compared against a risk matrix, in relation to the uncertainty of climate change impacts and the uncertainty in valuation. Mapping the literature studies onto this matrix, the research found that very few studies cover any non-market damages, or the risk of potential extreme weather (floods, storms, etc). None covers socially contingent effects, or the potential for longer-term effects and catastrophic events. Therefore the uncertainty in the SCC value concerns not only the 'true' value of impacts that are cov-

[2] *Climate Framework for Uncertainty, Negotiation and Distribution* (*FUND*, Integrated Assessment Model, Research Unit Sustainability and Global Change, Hamburg University and Centre for Marine and Atmospheric Science.

ered by the models, but also uncertainty about impacts that have not yet been quantified and valued. Perhaps most importantly, it indicates that values in the literature are a subtotal of the full SCC (though we do not know by how much)".

The Stern Review was another major review of the social costs of carbon. The review assessed the economics of moving to a low carbon economy, focusing on a medium to long term, plus the potential of different approaches to adaptation and lessons for the UK, in the context of climate change goals. From a review of the evidence, the report concludes that the benefits of strong and early action far outweigh the costs of not acting. Climate change will affect the basic elements of life for people globally – including in relation to access to water, food production, health and environment, potentially affecting hundreds of millions of people. Using the results from an integrated assessment model (the PAGE model), the review estimated that the total damage costs of climate change could be at least 5% of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more. The review suggested a SCC of € 85 per ton of CO_2, which is considerably higher than the UK government's "illustrative value" of € 28 per ton, and also far out in the right tail of Tol's probability density function (see above). In contrast to these high costs of inaction, the costs of action – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can, according to Stern, be limited to around 1% of global GDP each year.

The numerical results of studies into the external costs of greenhouse gas emissions remain speculative, but they can provide insights on signs, orders of magnitude, and patterns of vulnerability. Results are difficult to compare because different studies assume different climate scenarios, make different assumptions about adaptation, use different regional disaggregation and include different impacts. The Nordhaus and Boyer (1999) estimates, for example, are more negative than others, partly because they factor in the possibility of catastrophic impact. The Mendelsohn et al. (1996) and Tol (2002) estimates, on the other hand, are driven by optimistic assumptions about adaptive capacity and baseline development trends, which results in mostly beneficial impacts. According to Tol, the current generation of aggregate estimates may understate the true cost of climate change because they tend to ignore extreme weather events; to underestimate the compounding effect of multiple stresses; and to ignore the costs of transition and learning. However, these studies may also have overlooked positive impacts of climate change and not adequately accounted for how development could reduce impacts of climate change. Tol suggests that our current understanding of (future) adaptive capacity, particularly in developing countries, is still too limited to allow a firm conclusion about the direction of the estimation bias. Estimates of global impact are sensitive to the way figures are aggregated. Because the most severe impacts are expected in developing countries, the more weight is assigned to southern countries, the more severe are aggregate impacts. Using a simple adding of impacts, some studies estimate small net positive impacts at a few degrees of warming, while others estimate small net negative impacts. The need for synthesis and aggregation in the assessment of the costs of climate change poses challenges with respect to the spatial and temporal comparison of impacts. Aggre-

gating impacts requires an understanding of (or assumptions about) the relative importance of impacts in different sectors, in different regions and at different times. The task is simplified if impacts can be expressed in a common metric, but even then aggregation is not possible without value judgements. Azar (1999), Azar and Sterner (1996) and Fankhauser et al. (1997, 1998) discuss regional aggregation; Arrow et al. (1996) and Portney and Weyant (1999) discuss aggregation across time and across sectors.

Another crucial issue raised by Tol is the need to move from a static analysis to a dynamic representation of impacts as a function of shifting climate characteristics, adaptation measures and exogenous trends like economic and population growth. Among the few explicitly dynamic analyses are Sohngen and Mendelsohn (1999), Tol (2002), Tol and Dowlatabadi (2001) and Yohe et al. (1996). These studies are highly speculative, as the underlying models only provide a very rough reflection of real-world complexities. While some analysts still work with relatively smooth impact functions (e.g. Nordhaus and Boyer 2000), there is accepted recognition (e.g., Tol, 1996, 2002; Mendelsohn and Schlesinger 1999) that the climate impact dynamics, i.e. the conjunction of climate change, societal change, impact, and adaptation, is non-linear, and might be quite complex.

Table 1 presents a characterisation of the estimates of the studies reviewed by Tol (2005). It presents their central estimates (in USD per tonne carbon), their uncertainty ranges (if known), and a range of parameters and assumptions that are important for the interpretation of the results.

Table 1– Characteristics of the Marginal Costs Estimates

(C.Est. = Central estimate; Unc. Range = Uncertainty range; CDR = Consumption discount rate; PRTP = Pure rate of time preference; TH = Time horizon; EW = Equity weighted; AW = Author weight; PR = Peer-reviewed; New = New impact study; MC = Marginal cost methodology; Dyn = Dynamic impact study; Scen = Realistic climate scenario)

Source	C.Est.	Unc. Range	CDR	PRTP	TH	EW	AW	PR	New	MC	Dyn	Scen
Nordhaus (1991)	26.8			1	2100	N	1	Y	Y	N	N	N
Cline (1992)		5.8-124.0[a]			2500	N	1	N	Y	Y	N	Y
Nordhaus (1993)	5.0			3	2500	N	1	Y	N	Y	N	Y
Peck & Teisberg (1993)	10.0			3	2100	N	1	Y	N	Y	N	Y
Reilly & Richards (1993)	14.3		5		2100	N	.5	Y	N	Y	N	N
	21.2		5		2100	N	.5					
Fankhauser (1994)	20.3	6.2-45.2[a]			2100	N	1	Y	Y	Y	N	Y
Nordhaus (1994)	5.3			3	2500	N	1	N	Y	Y	N	Y

Source	C.Est.	Unc. Range	CDR	PRTP	TH	EW	AW	PR	New	MC	Dyn	Scen
Maddison (1995)	16.5		5		2100	N	1	Y	N	Y	N	Y
Plambeck & Hope (1996)	3.0	1.0-6.0[a]	5		2200	N	.3	Y	Y	Y	N	Y
	8.0	3.0-12.0[a]	5		2200	N	.1					
	8.0	6.0-18.0[a]	5		2200	N	.1					
	21.0	10.0-48.0		3	2200	N	.3					
	46.0	20.0-94.0[a]		2	2200	N	.1					
	440.0	390.0-480.0[a]		0	2200	N	.1					
Azar & Sterner (1996)	85.0			0	2300	N	4/90	Y	N	Y	N	Y
	200.0			0	3000	N	8/90					
	75.0			.1	2300	N	3/90					
	140.0			.1	3000	N	6/90					
	32.0			1	2300	N	2/90					
	33.0			1	3000	N	4/90					
	13.0			3	2300	N	1/90					
	13.0			3	3000	N	2/90					
	260.0			0	2300	Y	8/90					
	590.0			0	3000	Y	16/90					
	230.0			.1	2300	Y	6/90					
	410.0			.1	3000	Y	12/90					
	95.0			1	2300	Y	4/90					
	98.0			1	3000	Y	8/90					
	39.0			3	2300	Y	2/90					
	39.0			3	3000	Y	4/90					
Downing et al. (1996)	53.5		0		2100	N	.5	N	Y	N	Y	Y
	18.3		0		2100	N	.5					
Hohmeyer (1996)	800.0		0		2100	N	1	N	N	N	N	Y
Hope & Maul (1996)	7.0	3.0-11.0[a]		2	2200	N	.1	Y	Y	Y	N	N
	24.0	0.0-270.0[a]		2	2200	N	1					N
	5.0	2.0-7.0[a]		2	2200	N	.8					Y
	29.0	12.0-45.0[a]		2	2200	N	.1					N
Nordhaus & Yang (1996)	6.2			3	2500	N	1	Y	Y	Y	N	Y

Source	C.Est.	Unc. Range	CDR	PRTP	TH	EW	AW	PR	New	MC	Dyn	Scen
Nordhaus & Popp (1997)	11.6	0.0-34.0[b]		3	2500	N	.9	Y	N	Y	N	Y
	6.3			3	2500	N	.1					
Eyre *et al.* (1999)	170.0		1		2100	Y	.5	N	N	Y	Y	Y
	70.0		3		2100	Y	.5					
	160.0		1		2100	Y	.5					
	74.0		3		2100	Y	.5					
Roughgarden and Schneider (1999)	40.4	0.0-193.3[a]		3	2500	N	1	Y	Y	Y	N	Y
Tol (1999)	60.0	26.0-178.0[a]	3		2100	Y	.25	Y	Y	Y	Y	Y
	62.0		3		2200	Y	.05					
	23.0		3		2100	N	.05					
	66.0		3		2100	Y	.05					
	65.0		3		2100	Y	.05					
	56.0		3		2100	Y	.05					
	317.0	158.0-962.0	0		2100	Y	.05					
	243.0		0		2200	Y	.01					
	142.0		0		2100	N	.01					
	360.0		0		2100	Y	.01					
	348.0		0		2100	Y	.01					
	288.0		0		2100	Y	.01					
	171.0	81.0-512.0[a]	1		2100	Y	.05					
	172.0		1		2200	Y	.01					
	73.0		1		2100	N	.01					
	192.0		1		2100	Y	.01					
	187.0		1		2100	Y	.01					
	156.0		1		2100	Y	.01					
	26.0	11.0-77.0[a]	5		2100	Y	.10					
	26.0		5		2200	Y	.02					
	9.0		5		2100	N	.02					
	28.0		5		2100	Y	.02					
	28.0		5		2100	Y	.02					

Source	C.Est.	Unc. Range	CDR	PRTP	TH	EW	AW	PR	New	MC	Dyn	Scen
	25.0		5		2100	Y	.02					
	6.0	2.0-17.0	10		2100	Y	.05					
	6.0		10		2200	Y	.01					
	2.0		10		2100	N	.01					
	6.0		10		2100	Y	.01					
	6.0		10		2100	Y	.01					
	6.0		10		2100	Y	.01					
Nordhaus & Boyer (2000)	5.9			3[d]	2300	N	1	N	Y	Y	N	Y
Tol & Downing (2000	26.1			1	2100	Y	.1	N	N	Y	Y	Y
	3.5			1	2100	N	.1					
	45.8			1	2100	Y	1					
	5.1	3.2[c]		1	2100	N	.8					
Clarkson and Deyes (2002)	101.5	51.0-203.0[a]		1	2100	Y	1	N	Y	Y	N	Y
Tol (2002b)	19.9			0	2150	N	1/12	N	Y	Y	Y	Y
	16.1			0	2150	Y	2/12					
	3.8			1	2150	N	2/12					
	6.6			1	2150	Y	4/12					
	-6.6			3	2150	N	1/12					
	-0.5			3	2150	Y	2/12					
Pearce (2003)	23.5	6.5-40.5[a]		1	2100	Y	1	Y	Y	Y	N	Y
Mendelsohn (2003)		1.0-2.0 [a]		3	2100	N	1	N	Y	N	N	N
Newell and Pizer (2003)	5.7		4		2400	N	.10	Y	N	Y	N	Y
	10.4		4[e]		2400	N	.20					
	6.5		4[f]		2400	N	.20					
	21.7		2		2400	N	.05					
	33.8		2[e]		2400	N	.10					
	23.3		2[f]		2400	N	.10					
	1.5		7		2400	N	.05					
	2.9		7[e]		2400	N	.10					
	1.8		7[f]		2400	N	.10					

Source	C.Est.	Unc. Range	CDR	PRTP	TH	EW	AW	PR	New	MC	Dyn	Scen
Arithmetic mean	*97*	*203*[c]										
Author weights	*122*	*320*[c]										
Quality weights	*86*	*86*[c]										
Peer-reviewed only	*43*	*43*[c]										

[a] *90% confidence interval.*[b] *80% confidence interval.*

[c] *Standard deviation.*

[d] *The discount rate falls over time; the initial discount rate is specified.*

[e] *The discount rate falls over time according to a random walk model; the initial discount rate is specified.*

[f] *The discount rate falls over time according to a mean-reverting model; the initial discount rate is specified.*

Source: Tol, R. (2005), The Marginal Damage Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties, Energy Policies, 33(16)

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