Assessing the Impacts of Extreme Weather Events on Transport Systems – the Case of German Roads

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Abstract

The consequences of climate change get more and more visible, amongst others by more frequent and more intense extreme weather events. The heavy forest fires in Southern Europe during the last years as well as heavy floods, winter temperatures cracking road pavements, heat and cold periods blocking the railways and heavy storms forcing airports to close are illustrative examples. The economic costs associated with these extremes for the transport sector and the issue of appropriate and efficient adaptation measures is addressed by the research project WEATHER (Weather extremes: Impacts on Transport Systems and Hazards for European Regions) funded by the European Commission and running from November 2009 to April 2012. After a short literature overview we turn our attention towards the problem of recording impacts and costs and to questions of economic impact assessment. The second part or the paper then copes with the design of vulnerability indicators, the problem of value transferability and finally discusses the findings and propose further research steps.

Keywords: Climate change, weather extremes, vulnerability, risk indicators, adaptation, economic assessment

Outline of the Paper

1 Background: The WEATHER Study

In the past decade the attention towards human contribution to climate change has risen rapidly and has reached its temporary high in 2008. During that time the European Union has started their Emissions Trading System (ETS) and many ambiguous energy, housing and transport programs have been fostered. But the world economic crisis with its dramatic impact on policy priorities has shown how volatile the takling of such highly important but very long term problems can be. Sure, global warming has not been removed totally from policy agendas and there are still studies and implementation projects funded. But, as the example of the UK shows impressively, research money is among the first to be cut to maintain welfare in western countries and the failure of the Copenhagen world summit eventually seriously questions the long-term orientation and the sense for global fairness of the industrialised part of the world.

But the consequences of climate change get more and more visible. Longer and dryer summers, colder and stormier winters and increases in heavy precipitation events are observed even by the mild regions of middle Europe. Although in other parts of the world, such as in the U.S. and in the Pacific region these intensive phenomena are more amplified, also Europe will face considerable additional costs in the future. The heavy forest fires in Southern Europe during the last years as well as heavy floods, winter temperatures cracking road pavements, heat and cold periods blocking the railways and heavy storms forcing airports to close are illustrative examples. These events cause considerable additional costs to public decision makers and private firms, and thus could return attention back upon global warming issues.

Addressing climate change can be done from two sides: the mitigation of greenhouse gas emissions and the preparation of the affected economic sectors by suitable crises prevention and adaptation programs. From an economic perspective both approaches need to be followed as a sound combination out of mitigation and adaptation allows maximising social welfare whilst minimising the costs of doing so (Jochem, Schade 2009). The issue of appropriate and economically efficient measures is addressed by the research project WEATHER (Weather extremes: Impacts on Transport Systems and Hazards for European Regions) funded by the European Commission and running from November 2009 to April 2012. The study analyses the costs faced by transport operators, infrastructure managers and users due to extreme weather events and, in front of this background, judges the economic efficiency of certain short and long-term crises preparation and adaptation strategies for all modes of transport in Europe.

This paper presents first results of the vulnerability assessment of transport by focussing on road transport in and around Germany. After a short literature overview (Section 2) we turn our attention towards the problem of recording impacts and costs (Section 3), to questions of economic impact assessment (Section 4). The second part or the paper then copes with the design of possible vulnerability indicators (Section 5), the problem of value transferability (Section 6) and will finally discuss the findings and propose further research steps (Section 7).

2 Evidence from International Literature

The review of international literature on the topic of impacts of extreme weather events on transport leads to a substantial amount of publications, which are primarily issued in North America and the Pacific area. With (Gardiner et al. 2008) for New Zealand, (TRB 2008) for the U.S. and (Lemmen, Warren 2004) for Canada, transport-specific national inventories on the vulnerability of transport systems to climate change have been carried out.The extreme impacts by the hurricanes Katrina and Rita on the U.S. east cost have further motivated specific studies, including (Gallivan et al. 2009) for U.S. ports, (Savonis et al. 2008) for the Gulf Coast region or (Padgett et al. 2008) on bridge damages and reconstruction costs.

The European Commission has issued a White Paper on climate adaptation in the EU in 2009 (EC 2009), but without addressing the transport sector. However, some specific studies can be found on member state level, including (Saarelainen 2006) for Finland, (Bengtsson, Tómasson 2008)for Iceland roads and (Lindgren et al. 2009) for Swedish railways. In some of the larger EU Member States, including Germany, France and the UK, general adaptation programs are under way; respective attempts are however missing for the southern and eastern part of the Union. Studies addressing Europe as a whole are missing, which may be due to the common assumption that climate change impacts for Europe are – in contrast to other world regions – manageable (Hoffmann et al. 2009).

These studies have well investigated the principal impacts that climate change and extreme weather events may impose on transport infrastructure and on system operations. But due to the broadness of the transport sector, the uncertainty with local climate impacts and seldom occurrence of weather extremes the studies remain descriptive in nature. However, a number of following up on past hazards, such as Katrna and Rita at the US east coast, provide useful insights into monetary impacts of similar events. And further new databases on extreme events and their impacts are emerging, including the reports from the major Reinsurance companies (Munich RE 2010; Swiss

Re 2008) and publically accessible services like EM-DAT international disaster database, operated by CRED (UCL) and supported by the WHO (Vos et al. 2010). The paper will present a review on current literature on the effects of extreme weather events on transport worldwide and will identfy gaps in knowledge with respect to the European situation.

3 Options for Extending the Knowledge Base

We have assessed the studies reviewed in Section 2 with respect to specific damage cases and the reporting of costs. This way of looking at existing literature is essential for the further project work as we need to get as close as possible to the point what the detailed consequences of the different extreme events for transport infrastructure and operations are. Therefore we have classified the reported incidents by type of event, by damage class, by mode, transport sector, affected body and by geographical region. In the road transport sector we have reveiwed around 100 damage cases in about 21 studies. This rather moderate amount of damage cases and incidents evaluated constitutes an intermediate state of work and i s about to be extended during the coming weeks. Thus, the result of this “classified literature review” can only give an indication, rather than a final picture on the availability of appropriate information on transport sector vulnerabilities. Figure 1 and Figure 2 provide some insight into the number of damage cases reported in the studies, which have been reviewed so far.

For a sound assessment of the impacts of extreme weather events on transprot infrastructures and transport users the general statements of current studies are not sufficient. In this respect, insurance reports are also of limited value only, as they commonly do not distinguish between the sectors affected and do not contain non-material damage categories. To expand the knowledge base, the WEATHER project has performed an extensive media research in selected European Member States. Besides simple internet searches we have addressed the archives of national newspapers and journals, including general press and transport-specific media.

The literature survey provides valuable input into the question what has happened to which degree of severity due to which type of extreme with detailed geographical references. In the paper we will present the results of the media review for Germany and the UK and compare the findings to the outcome of the literature review.

4 The Economic Assessment

A sound assessment of the likely economic impacts of climate change and extreme weather events on Transport systems is essential for designing appropriate adaptation measures. In this sense the assessment should include all cost categories which might be affected by preparation strategies, including replacement, repair and operating costs of infrastructures, transport services and private vehicles, time costs of users, safety related costs and environmental impacts. But on most of these indicators reliable and comprehensive records are not available or, as in the case of user time costs and immaterial accident consequences, do not even exist.

For this reason the WEATHER project has elaborated a general assessment framework (GAF) , which allows to derive economic cost estimates out of qualitative impact reports. This framework is based on standard cost values, assumptions on average national network configurations and traffic volumes as well as on semantic transformation tables to “guess” quantitative figures out of verbal expressions like “few” or “many”.

We acknowledge that uch estimates are extremely vague. But given the current state of knowledge concerning the economic impacts of extreme weather events on the transport sector these “guestimates” promise to bring considerable new insight into the level and structure of damage costs into play. Within the WEATHER project such a data base is essential in order to judge the economic soundness of certain adaptation strategies. In the paper we will present the assessment framework, demonstrate it at some examples for road transport in Germany and the UK and compare the results to the available estimates.

5 The Concept of Risk Indicators

Extreme weather events comprise a wide palette of different hazards arising from wind-related activities, temperatures and precipitation, as well as consequences of these primary weather phenomena. This paper concentrates on singular weather events which clearly exceed the long-term average of comparable meteorological activities over the annual mean or related to the specific season, which have considerable negative impacts on assets and operations, or which affect human health or lives. These definitions are vague by nature as normal seasonal conditions change over decades and across regions. We acknowledge the importance of forecasting weather probabilities as climate conditions will change in the coming decades, but for reasons of transparency we remain with the current situation in this paper.

We categorise extremes according to the primary meteorological phenomenon (wind, precipitation or temperature) or as consequent events caused or amplified by meteorological extremes. Non-meteorology-inflicted geo risks, such as earthquakes and volcanic eruptions, as well as long-term consequences of global warming, e.g. the rise of sea water levels or thawing of permafrost soil, are out of scope of the weather research as long as they do not impact the severity or duration of extreme events. Table 1 gives an overview of the categories of extremes considered here.

In the past years a large number of research projects and data sources on weather extremes have emerged. Most important sources on international level are the IPCC assessment reports and work put forward by the World Meteorological Organisation (Klein Tank et al. 2009). In the European research scene we find activities like the ENSAMBLES project (van der Linden, Mitchell 2009) and its proceeding activities. The objective of the project is to generate climate and weather trends for different European regions on a differentiated local scale. The project provides rich and extremely differentiated data sources on temperature and precipitation related trends and on the probability for extremes. Weather extremes are expressed by the concept of “return values”, describing the most severe event of a category within a given time interval. A set of more straight-forward geo-risk indicators for European regions is provided by the ESPON project (Schmidt-Thomé et al. 2006) of the EM-DAT database (Vos et al. 2010).

The indication of extreme weather intensities alone, however, is not sufficient to judge the vulnerability of a region. In addition, information on the number of sensitive assets and activities, which may be affected in the emergency case, is required. In terms of transport this is the density of the various network types and the volume of passenger and freight traffic performed on them. Both indicators are available at Eurostat on NUTS-2 level. For some types of weather events, e.g. storm surges, floods, avalanches, landslides and wild fires, the NUTS-2 level is too coarse. For this reason we use the infrastructure and volume databases of the European transport model TRANS-TOOLS to generate network and volume density indicators on NUTS-3 level.

Connecting these density indicators with weather intensity values finally provides an idea of the relative vulnerability of certain regions in the European context. The purpose of such indicators then is to transfer estimates of economic losses for certain categories of extremes between European regions to get an idea of the overall impacts on a European scale. Although we are well aware that these indicators and the intensity of the respective consequences differ largely across weather categories and thus simple average values are meaningless, we have demonstrated how such a combination may look like in Table 2 to Table 4 in the annex. In the final paper we will present more detailed regional indicators for selected categories of extreme events.

6 Cost Transfer across Europe

Despite the availability of regional weather intensity indicators and local transport network and demand densities, the problem of transferring results from a few countries to Europe is far from trivial. In this section we will discuss various value transfer mechanisms and their limitations. As far as available data allows we will present illustrative results from extrapolating German data to selected other countries, which are not too different from their climate conditions. Possible candidates are France, the Benelux countries, the UK or some eastern European Member States.

7 Conclusions and Outlook

The approach to quantify the economic impacts of extreme weather events on transport still reflects work in progress. For achieving an acceptable level of confidence a number of methodological problems still have to be solved, including the determination of affected road users, the understanding of infrastructure deterioration processes and the relationship between weather and traffic safety. Moreover, similar results have to be produced for rail, air and waterborne transport and additional research is required in terms of value transfer across different regions and climateic zones of the Community.

In a final section the paper will assess the results found in this paper for German road transport and its transfer to other countries in front of these further research requirements. It will also give an outlook on the further work of the WEATHER project, which includes the design of suitable adaptation strategies, the conduction of case studies and issues of policy design.

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9 Annex: Tables and Figures

Table 1: Categories of extreme weather events

Categories of events		Explanation	Relevance by region and / or season	Relevant for mode
Temperature	Heat	Several consecutive days exceeding 35°C with single days exceeding 38°C	Northern countries not accommodated to high temperatures	Infrastructure surface, electric components, energy demand, safety, comfort
	Frost	Several consecutive weeks remaining below -5°C daily maximum	Middle and southern European states not accommodated	Infrastructure surface, ice formation, energy demand, safety, confort
Precipitation	Rainfalls	Strong single event or consecutive day exceeding 200 mm	All Europe, particularly severe in mountain areas	Drainage system overloads, inundation, infrastructure destruction, safety, comfort
	Snow	Longer period with snow level exceeding a given minimum.	Southern and middle Europe with varying thresholds	Snow removal, safety, comfort
	Hail	Hail with bigger hailstones		Damage to vehicles, safety
	Drought	Several consecutive weeks with minimal rainfalls	Southern and partly middle Europe	Inland shipping depending on impact on water levels
Wind	Storms	Events with wind speeds exceeding a certain level	British Islands, middle Europe	Infrastructures (bridges, overhead wires, etc.), service interruption, safety
	Storm surges	Wind speeds and water levels exceeding certain levels	North-western Europe along coast lines.	Large-scale infrastructure destructions, safety
Atmosphere	Fog	Longer periods with frequent sight below a certain distance	Mountain and northern coast line	Speed reduction, cancellation of services, safety
	Ash could	Volcano ash or other particles in bigger quantities in the atmosphere	All Europe	Air transport safety and cancellation of services
Consequences	Wild fires	Uncontrolled fires covering a bigger areas t	Southern Europe	Destruction and blocking of infrastructures, safety
	Floods	Water levels exceeding a given threshold	All Europe around river systems	Destruction and blocking of infrastructures, damage to vehicles, safety
	Flash floods	Flooding in less than 6 hours	Geomorphic low lying areas	Destruction and blocking of infrastructures, damage to vehicles, safety
	Landslides	Minimum area covered by slipping ground	Mountain areas	Destruction and blocking of infrastructures, damage to vehicles, safety
	Avalanches	Rapid flow of snow down a slope	Mountain areas	Blocking of infrastructures, vehicle damage, safety

Source: Fraunhofer-ISI

Figure 1: Literature database evaluation by country

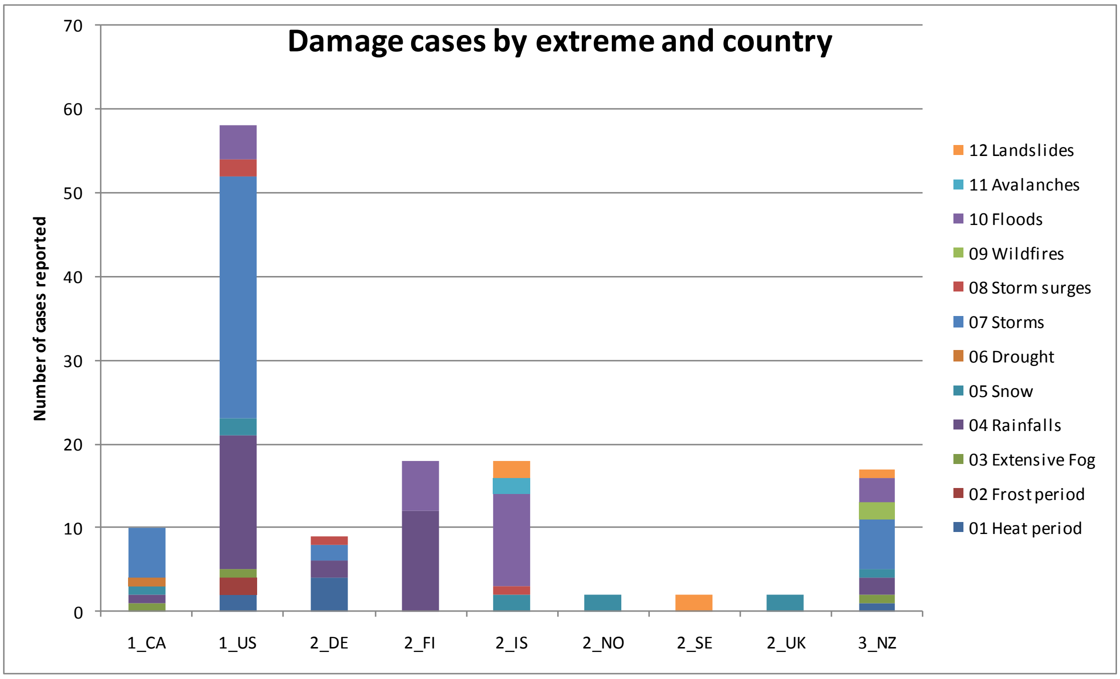


Figure 2: Literature database evaluation by impact category and actor

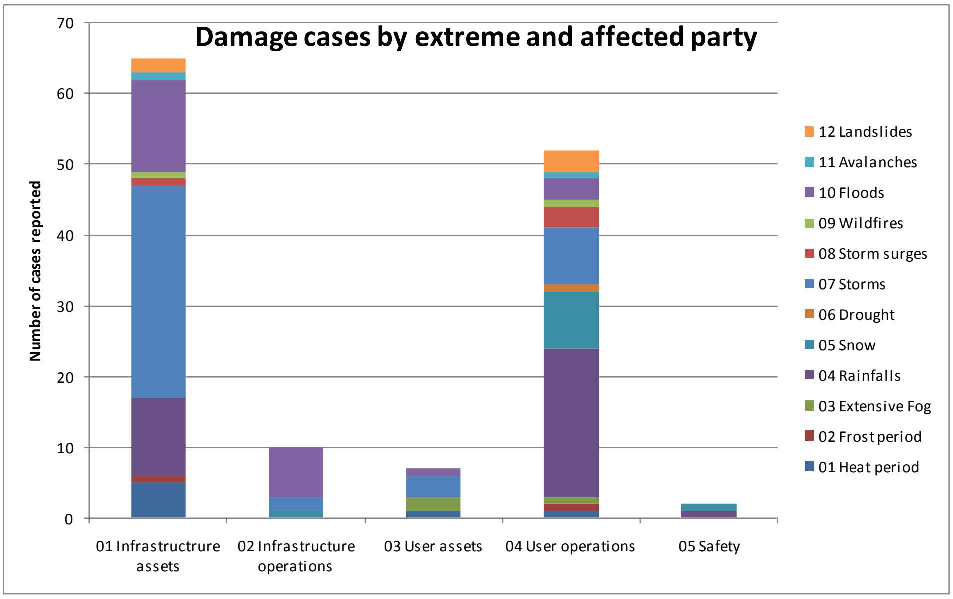
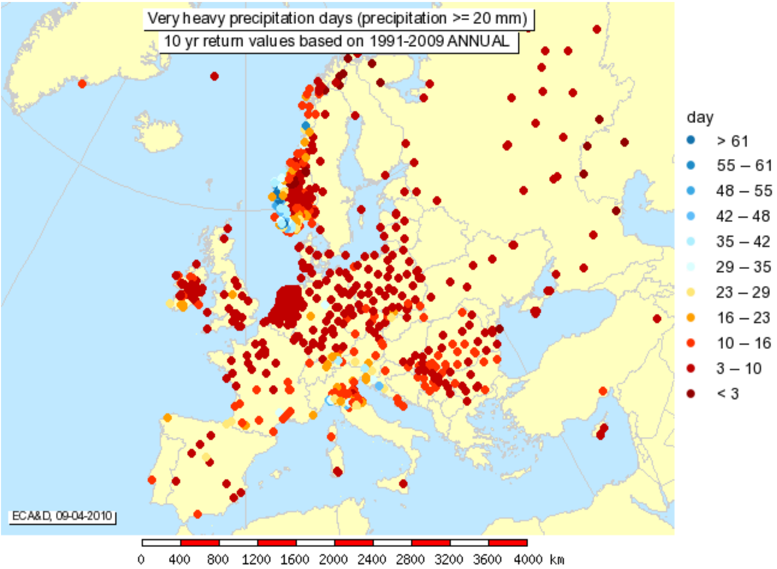


Figure 3: 10 year return value of heavy precipitation



Source: ECA&D Database: http://eca.knmi.nl

Table 2: National probabilities for selected geo risks

Country	Storms	Storm Surges	Extr. tempe-ratures	Drouhgts	Wild fires	Floods	Land-slides	Ava-lanches	Hazard index (max=100)	Country ranking
Denmark	5	5	2	4	2	1	3.5	0	56	1
Switzerland	3	0	2.5	3	1.5	3.5	4	3	51	2
Norway	5	0	2.5	3.5	1.25	1	4	3	51	3
Germany	3.5	1.25	2.75	4	2	3.5	3	0	50	4
Un. Kingdom	5	2.5	2	2	1.5	3	4	0	50	5
Portugal	3	1.25	2	5	4	1.5	3	0	49	6
Luxembourg	3	0	2	4	3	3	4	0	48	7
Netherlands	5	2.5	2	4	1	2	2	0	46	8
Bulgaria	1	0	3.25	4	3	1.5	4	1.5	46	9
Poland	4	1.25	3	4	2.5	1.5	2	0	46	10
Czech Rep.	3	0	3	4	2.5	2.5	3	0	45	11
Romania	1	0	3.25	3	2.5	4	3.5	0.75	45	12
Austria	2	0	2.5	3	1	2	4	3	44	13
Belgium	5	0	2	4	1.5	3	2	0	44	14
Finland	3	2.5	3.5	1	2	1	3	1.5	44	15
France	4.5	0	2	2.25	2	3	3	0.75	44	16
Spain	3	0	2.25	3	3.5	2	3.5	0	43	17
Cyprus	1	0	3	4	4	1	4	0	43	18
Greece	1	0	2.5	4	4	1.5	4	0	43	19
Slovakia	2	0	3	3	2	2.5	3.5	0.75	42	20
Sweden	3	2.5	2.75	2	2	1	2	1.5	42	21
Ireland	5	0	2	2	2	2	3.5	0	41	22
Italy	2.5	1.25	2	1.5	3	2	3.5	0.75	41	23
Lithuania	3	0	3	4	2.5	1	3	0	41	24
Slovenia	1	1.25	2.5	3	2	1	3.5	1.5	39	25
Estonia	3	2.5	3	1	2	1	3	0	39	26
Latvia	3	0	3	2.5	2	1	3	0	36	27
Hungary	1	0	3.25	3	2.5	1.5	3	0	36	28
Malta	1	0	2	1	4	1	2	0	28	29
EUR27 total	2.95	0.82	2.57	3.06	2.37	1.91	3.22	0.62	44	15

Source: Data from the ESPON project: www.gsf.fi/projects/espon/natural.htm

Table 3: National densities of road networks and traffic flows

Country	area (1000 km²)	Network density index (EUR27=100)	Vehicle-km density index (EUR29=100)	Overall system density (EUR29=100)	Country ranking
Malta	0.3	651	646	649	1
Denmark	43.1	498	117	308	2
Luxembourg	2.6	226	245	236	3
Un. Kingdom	243.8	155	266	211	4
Netherlands	41.5	59	339	199	5
Italy	301.3	160	229	195	6
Germany	357.1	154	231	193	7
Belgium	30.5	14	347	180	8
France	544.0	215	127	171	9
Switzerland	41.3	136	191	163	10
Czech Rep.	78.9	191	88	140	11
Slovenia	20.3	75	116	96	12
Austria	83.9	87	84	85	13
Spain	506.0	86	67	76	14
Greece	132.0	72	73	73	15
Slovakia	49.0	89	52	71	16
Cyprus	9.3	65	60	63	17
Lithuania	65.3	69	55	62	18
Hungary	93.0	78	44	61	19
Ireland	70.3	51	67	59	20
Latvia	64.6	89	25	57	21
Romania	238.4	84	29	56	22
Poland	312.7	28	84	56	23
Estonia	45.2	85	22	54	24
Portugal	92.1	15	90	53	25
Bulgaria	111.0	45	37	41	26
Sweden	450.3	57	21	39	27
Norway	323.8	26	17	22	28
Finland	338.4	12	18	15	29
EUR29 total	4689.9	100	100	100	

Source: EUROSTAT data

Table 4: Aggregated national road transport exposure indicators

Country	Intensity of hazards (max=100)	Transport system density (EUR29=100)	Overall transport exposure	Country ranking
Malta	28	649	178	1
Denmark	56	308	173	2
Luxembourg	48	236	112	3
United Kingdom	50	211	105	4
Germany	50	193	96	5
Netherlands	46	199	92	6
Switzerland	51	163	84	7
Italy	41	195	80	8
Belgium	44	180	79	9
France	44	171	75	10
Czech Republic	45	140	63	11
Slovenia	39	96	38	12
Austria	44	85	37	13
Spain	43	76	33	14
Greece	43	73	31	15
Slovakia	42	71	30	16
Cyprus	43	63	27	17
Portugal	49	53	26	18
Poland	46	56	26	19
Lithuania	41	62	26	20
Romania	45	56	25	21
Ireland	41	59	24	22
Hungary	36	61	22	23
Estonia	39	54	21	24
Latvia	36	57	21	25
Bulgaria	46	41	19	26
Sweden	42	39	16	27
Norway	51	22	11	28
Finland	44	15	7	29
EUR27 average	28	100	28	

Source: Fraunhofer-ISI