ClimateCost

Policy Brief

The Costs and Benefits of Adaptation in Europe: Review Summary and Synthesis

This briefing note summarises the review and synthesis work on the costs (and benefits) of adaptation to climate change in Europe[1]. The research received funding from the European Community's Seventh Framework Programme[2].

The review has covered European, sectoral, regional and national studies, as well as global studies that report information for Europe. This information is important in raising awareness of potential adaptation needs, providing a first indication of possible adaptation financing needs, and in providing information to help develop European level and Member State strategies for adaptation.

Key findings are outlined below:

- The review has found that the coverage of the adaptation cost estimates is limited, though the evidence base in now growing (though it is primarily in the grey literature).
- Around 50 studies of the costs of adaptation in Europe have been found and reviewed. The findings are summarised below, by sector, region and country.
- The existing sectoral information on adaptation costs has a very uneven distribution.
- The largest number of studies, and those with most sophistication, exist for the coastal zone sector, where European wide, regional, national and local-scale examples can be found.
- These coastal studies use a wide range of methods, including impact assessment based adaptation analysis, macro-economic model assessments of adaptation costs, risk management assessments, cost-benefit analysis, cost-effectiveness analysis and portfolio/real options analysis. There are also a number of cross sectoral studies emerging, which look at the indirect effects of coastal flooding on e.g. health and tourism.

For other sectors the coverage is more limited. The studies are summarised in the table below. In summary:

- There are several European and national level studies on the costs and benefits of energy demand for heating and cooling (autonomous adaptation).
- There are some estimates of adaptation costs in the health sector, but these tend to be limited to a small number of adaptation measures (e.g. heat alert systems and some preventative or reactive treatment).
- There are agricultural studies of autonomous (farm level) adaptation, but relatively few that include planned adaptation.

[1] Prepared by Paul Watkiss and Alistair Hunt, as part of the EC 7th FWP ClimateCost Study, based on work by the ClimateCost Consortium. This review has also benefited from review work as part of work for the European Environment Agency as part of the input to the SOER, 2010, and also review work by this team for the UNFCCC (2009) and from UK Defra as part of the UK Adaptation Assessment. Version1, March 2010.

[2] The information in this note reflects the author's views and the Community is not liable for any use that may be made of the information contained therein.

SEVENTH FRAMEWORK PROGRAMME

Coverage of Adaptation Studies in Europe

Sector	Coverage	Cost estimates	Benefit estimates
Coastal zones	Very high coverage (infrastructure/erosion) for Europe, regions, several Member States as well as cities/local examples	✓✓✓	✓✓✓
Energy	Medium. Cooling / heating demand (autonomous adaptation) for Europe, some MS. Less on planned adaptation and supply*	✓✓	✓✓
Infrastructure	Medium – adaptation cost estimates in several countries for flooding, but lower coverage of other infrastructure risks	✓✓	✓
Agriculture	High coverage of farm level adaptation benefits, but much less on costs and on planned adaptation	✓	✓✓
Health	Low – Medium. Adaptation costs for heat alert and food borne disease, but less coverage of other health risks	✓	
Water	Low – Medium. Limited number of national, river basin or sub-national studies on water supply.	✓	
Transport	Low – Medium. Some national and individual sector case studies	✓	
Tourism	Low - studies of winter tourism (Alps) and some studies of autonomous adaptation from changing summer tourism flow*	✓	✓
Forestry and Fisheries	Low - limited number of quantitative studies	✓	
Biodiversity / ecosys. services	Low - limited number of quantitative studies	✓	
Business and industry	Very low – no quantitative studies found		
Adaptive capacity	Low – selected studies only and only qualitative descriptions of benefits	✓	

See main text for discussion and caveats
*note can be considered an impact or an adaptation.

Key
✓ Low coverage with a small number of selected case studies or sectoral studies.
✓✓ Some coverage, with a selection of national or sectoral studies.
✓✓✓ More comprehensive geographical coverage, with quantified cost (or benefit) estimates at aggregate levels.

- There are also studies for the water sector (water resources and floods) and tourism.
- There remains little quantified information on the costs or benefits of adaptation in protecting biodiversity and ecosystem services or for industry and business sectors.
- There is also only very limited consideration of the costs of building adaptive capacity.
- There are a number of studies that focus on vulnerable regions of Europe, and reveal important regional differences.
- These include assessments of the costs of sea level rise in Western Europe, the costs of adaptation for tourism in the Alps, and forthcoming work for the Mediterranean (health, cooling demand and water availability) and the Baltic.
- Finally, there are a number of national studies that have undertaken more comprehensive adaptation cost assessments, though these also have partial coverage only. The most detailed national information is available for the Netherlands, Sweden and the UK.

Even within this small group of assessments, a range of different methodological approaches are adopted, with costs of adaptation being reported in different metrics, time periods, etc. A large number of other European national studies will be published over the next few years, and many of these are assessing the costs of adaptation. In general, less information is available for new EU member states.

The studies above use a range of methods and metrics, for different time periods, with different assumptions for treatment of changing socio-economic conditions.

Consequently it is very difficult to compare estimates between studies, i.e. to undertake a systematic review and build up a coherent picture of the overall costs of adaptation in Europe. Nonetheless, the information from these studies can provide some early context on the possible costs of adaptation in Europe and highlight important issues.

Some of the main costs estimates are summarised below. These costs are separated into three groups of studies:

1) Estimates of European adaptation costs in global aggregated studies

2) European specific sectoral assessments of costs – and finally

3) Adaptation cost estimates from national studies.

These different 'lines of evidence' have also been compared to see whether they report similar adaptation costs.

1) Global estimates.

Some of the international estimates and economic integrated assessment models do provide European estimates as part of global analysis.

As examples, the ***Investment and Financial Flow Assessments*** provide indicative adaptation costs for OECD Europe for the short-term

- The UNFCCC (2007) review reported indicative adaptation costs of $3 - 19 billion/year by 2030 for two sectors (infrastructure and coastal zones) in Europe, whilst estimates given in the Stern Review (based on costs of 0.05 to 0.5% GDP) imply adaptation costs for infrastructure for Europe of €4 to 60 billion/year. Both these estimates are highly uncertain, as they are based on simple scaling of likely investment needs.

The ***economic Integrated Assessment Models*** also report a wide range.

- Some models use I&FF estimates so report similar adaptation costs (e.g. the PAGE model inputs are based on Stern analysis, so assumes adaptation costs for the EU15 of $25 to $60 billion per year with a mean estimate of $ 45billion/year).

- Other IAM studies report much lower adaptation costs. For example, the ADAM project (Aaheim et al, 2010) aggregate modelling analysis reported adaptation costs in Western Europe in 2020 are 0.04% of GDP ($5 billion) rising to $35 billion in 2050 (0.13% of GDP) assuming a 2ºC scenario.

- The OECD (de Bruin et al 2009) study estimates total weighed adaptation cost for a 2.5 degree temperature rise at 0.64% of total output for Europe and 0.14% for the Eastern Europe.

However, these IAM estimates are highly aggregated and very uncertain.

2) European and sector studies

The ***sectoral studies*** also provide some comparative information on adaptation costs.

- The PESETA coastal study reports costs of €0.25 to 1 billion/ ear in the period 2010 – 2040 (across a range of sea level rise scenarios), and €0.3 to 2.6 billion/year in the period 2070 – 2100. The study also reports that the economic benefits of adaptation (in

reducing costs of inaction) far outweigh the costs.

- For health, there are estimates of the costs of adaptation for diarrhoeal disease in Europe (based on costs of health interventions: Ebi, 2008: Markandya et al 2009), which report annual adaptation costs up to the year 2030 for Europe at $12 to 260 million / year for a range of scenarios and assumptions. There are also a number of studies that review heat alert costs implemented in Europe. Other sectoral estimates exist for the electricity sector.

These aggregate sectoral estimates indicate potentially large adaptation costs in Europe, e.g. billions of Euro per year in the short-term, potentially tens of billions per year in the longer-term.

However, they are highly aggregated studies, with partial coverage within sectors (e.g. omitting some adaptation needs across a sector).

There is also still a low sectoral coverage and very little information on adaptation costs in many potentially important sectors at European level (e.g. water supply, tourism, industry, biodiversity and ecosystems).

Moreover, it is stressed that assessing the costs of adaptation at the European scale is extremely challenging, involving high levels of aggregation and simplifying assumptions. There therefore remains a need to validate the estimates against more detailed, national and even local level analysis.

3) National and local studies.

There are a number of existing ***national level and case studies***. These also imply large adaptation costs, particularly for flood protection. These are often presented in terms of total investment needs over time.

- For example, the UK Foresight study estimated the total adaptation investment needed to address flooding (coastal, river and intra-urban) over the next 80 years at between £22 billion and £75 billion for a portfolio of responses, depending on the scenario, implying average annual costs of up to €1 billion per year.

- Similarly, a recently conducted assessment on flood protection and flood risk management in the Netherlands estimates that the implementation of a comprehensive set of adaptation measures will cost €1.2–1.6 billion per year up to 2050 and €0.9–1.5 billion per year during the period 2050–2100.

- The Swedish national study estimated potentially large investment costs for adaptation across a wider range of sectors (including transport, water treatment, infrastructure, flood protection) of up to €10 billion (total) in the period 2010-2100.

When scaled up to European level, these national studies (3 above) imply potentially higher adaptation costs than found in many of the more aggregate studies.

The size of the estimates even for individual risks (flooding) in individual countries indicate that the costs of adaptation in Europe may be higher than the existing sectoral studies – and certainly higher than many of the IAM studies, i.e. at the EU level, they potentially suggest costs of tens of billions/year when scaled to all countries and all sectors.

However, some caveats should be noted with these estimates also. In many cases earlier investments involve a mix of addressing current climate risks as well as future climate change.

They are often focused on technical adaptation and do not include possible behavioural change. Many of these investments would also take place within normal investment replacement cycles.

Finally, these studies rarely split out the marginal additional costs for climate change compared to those implied by socio-economic change, i.e. they do not separate out the investment that would be needed in the absence of climate change (e.g. the policy counter-factual) from that arising from climate change alone.

The costs of some individual projects could be very large, as shown by studies of potential high risks to coastal flooding and London (TE2100 project). However, most of these costs will fall in the longer-term. The immediate priorities for these risks are to develop iterative approaches that allow future decisions to be taken.

A map of some of the main studies on the costs of adaptation is shown below, showing a range of studies at different scales – from European wide assessments to more locally based case studies.

The review has highlighted a number of methodological issues.

Some of the most important relate to boundaries and definitions, as to what constitutes adaptation, and the overlap between impact (damage) and adaptation costs. For example, whether additional energy costs to meet higher cooling demand are included as an impact (damage) cost or an adaptation cost will depend on the study authors. Related to this, adaptation may be autonomous or planned, and the balance may be determined by the socio-economic change assumed and baseline assumptions.

Additionally, there can be difficult issues in the attribution between climate change and socio-economic development (including whether future socio-economic change is adequately included), and attribution issues between future climate change and current climate variability (and the current adaptation deficit).

There are also issues on whether 'net' costs should be reported, notably when there is a mix of costs and benefits from climate change (for example in the case of reduced winter heating energy versus increased summer cooling demand).

The varying studies have adopted different approaches for assessing adaptation – shown in the table over the page. These varying methods have strengths and weaknesses according to their context and objectives.

They provide different types of information, which addresses different policy questions, much of which is complementary.

No individual approach is likely, on its own, to adequately address all of the methodological aspects associated with adaptation, for all sectors, time-periods and aggregation levels. There are therefore benefits in adopting multiple methods and models, and subsequently linking these together to provide a larger and more informed evidence base.

The studies also adopt varied typologies and consider different options for adaptation. Many focus on hard (technical) adaptation and exclude - or have less coverage of - soft (non-technical) options. Most omit consideration of adaptive capacity, despite this being identified as a key priority from the non-economics adaptation literature.

Related to this, many studies of adaptation costs generally consider adaptation to be an outcome (from a menu of options), rather than also considering adaptation as a process, involving the development of institutional and individual capacity.

The general methodological frameworks also adopt different assessment tools (decision support tools) for prioritisating adaptation, which use information on the costs and benefits of adaptation.

These decision support tools include the use of cost-benefit analysis, cost-effectiveness analysis, multi-criteria analysis, real options assessment, etc.

Europe-wide specific assessments

- Coastal zones, e.g. PESETA (2009)/ PIK (2010); DG MARE (2009) – costs and benefits of adaptation for coastal zones, as well as earlier studies

- Energy – ADAM (2010) – costs of changes in heating and cooling demand (autonomous)

- Agriculture – benefits of autonomous farm level adaptation ,e.g. PESETA (2009): ADAM (2010) and other studies

- Health – European heat alert costs (e.g. WHO, 2008)

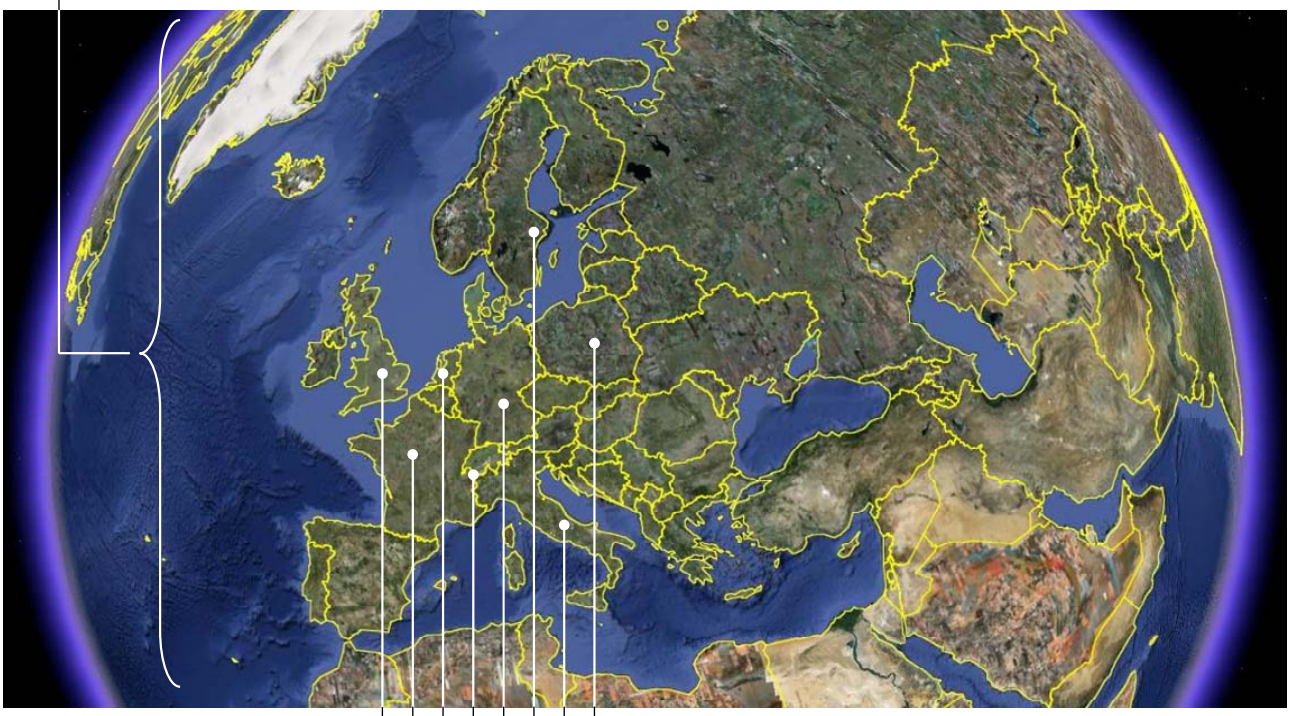
European estimates as part of global analysis

- Health (Ebi, 2008; Markandya et al, 2009) adaptation costs for some food and vector borne disease (as part of global analysis)

- UNFCCC (2007) – investment flows for OECD Europe; World Bank (2009) central and eastern Europe

- Global economic integrated assessment model outputs for Europe e.g. Hope (2009); de Bruin et al (2009); Carraro et al (2009); Aaheim et al (2010)

- Tourism flows (Hamilton and Tol, 2006)



Source: Paul Watkiss/ClimateCost Project: Map source: GoogleEarth

UK

UKCIP (2006) costing guidance and adaptation cost case studies (national costs of adaptation for subsidence)

Foresight Flooding (2004) costs and benefits of flooding (coastal, river, intra-urban)

Cross regional (Metroeconomica, 2006) – sectoral costs and benefits of adaptation for electricity, water, biodiversity sectors

Costs and benefits of adaptation for Hull for coastal flood risks (ECA, 2009)

Thames Estuary 2100 (EA, 2009) /HMT (2009) – flood risks for London - portfolio/real option

Costs of adaptation for water sector (ICF, 2007)

Costs of heat alert systems (WHO, 2008)

Costs of building adaptive capacity (Watkiss, 2010))

ONERC (2008). Damage costs and some autonomous adaptation estimates,, e.g. agriculture, energy

Studies on buildings (Hallegatte et al, 2007); adaptation costs of heat alerts (WHO, 2008)

Netherlands Routeplanner/ARK (2006) - Qualitative assessment of adaptation options (spatial planning) across a range of sectors and review and some estimates of adaptation costs and benefits

Flood risks in the Netherlands under climate change – estimates of costs of future coastal protection Delta Commission, 2008)

Costs of adaptation for flooding in the Netherlands (EEA, 2007)

Adaptation cost estimates (tourism) in the Alps (Abegg et al/OECD, 2007)

Costs of adaptation for Germany (macro-estimate) Kemfert (2007)

Sweden Commission on Climate and Vulnerability (2007). A assessments of adaptation investment needs for transport, tele-coms, energy, infrastructure, water and agriculture

Costs of adaptation for coastal flooding. Fondi plain case study (EEA, 2007)

Autonomous adaptation for Italy (macro-estimate) Carraro and Sgobbi (2008)

Benefits of reducing heat stress (Rome) Carraro et al 2009

Poland - adaptation costs for agriculture to extremes (Matczak et al, 2009)

Selection of Cost and Benefits studies of Adaptation in Europe

note some studies consider effects that can be considered an impact or an adaptation.

There are a range of examples of the use of these decision support tools, as outlined in the table below.

Examples of different decision support tools in adaptation in Europe

Decision support too	Example
Cost-benefit analysis	UKCIP costing guidance case studies (Metroeconomica, 2006)
Cost-effectiveness analysis	Adaptation for the water deficit in UK (Metroeconomica, 2006). Cost of health intervention as cost per DALY (e.g. UNFCCC, 2007) Widespread in coastal protection for cost-effectiveness analysis of meeting levels of protection.
Multi-criteria analysis	Adaptation in spatial planning (routeplanner) Netherlands (2006)
Pathway/real option analysis	Long-term sea level rise, e.g. London Thames Estuary 2100 (EA/HMT, 2009)

In summary, only a relatively small number of adaptation cost estimates are currently available, which have a partial coverage across potential risks and across all sectors. In some areas, there is a very large evidence gap.

There remains a large evidence gap and a need for more practical examples of different approaches in practice.

However, the existing evidence does serve to give an initial picture of the possible costs that may be incurred.

Moreover, a number of studies are now ongoing and these will help to build the evidence base. These include European wide studies (notably FWP7 projects), regional and sectoral assessments, and a large number of Member State initiatives which have a strong focus on adaptation costs and benefits.

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Methodological Frameworks and Models for Economic Assessment of Climate Change and Adaptation

Approach	Description	Examples	Advantages	Issues
Economic Integrated Assessment Models (IAM)	Global aggregated economic models that assess damage costs, and costs and benefits of adaptation. Values in future periods, expressed £ and %GDP and over time (PVs)	Global analysis of the costs and benefits of adaptation, with regional breakdown including Europe, e.g. Hope (2009) and de Bruin et al, (2009).	Provide headline values for raising awareness. Very flexible – wide range of potential outputs (future years, PV, CBA).	Very aggregated approach with highly theoretical form of adaptation, with no technological detail or consideration of uncertainty (see Patt et al, 2009). Insufficient detail for national or sub-national adaptation planning.
Investment and Financial Flows (I&FF)	Financial analysis. Costs of adaptation (increase against future baseline)	Global studies (e.g. UNFCCC, 2007). National studies, e.g. Sweden (2007) uses I&FF type approach. Detailed approach advanced by UNDP (UNDP, 2009)	Scale of short-term investment for enhancing resilience in plans. Flexible method that can be applied without detailed analysis of climate change.	Often no integral linkage with climate change scenarios, uncertainty or practical adaptation decision-making (though, in principle, can be included). .
Computable General Equilibrium models (GCE)	Multi-sectoral and macro-economic analysis for economic costs of climate change, and emerging analysis of adaptation	National level estimates for autonomous adaptation, e.g. Carraro and Sgobbi (2008), and national planned adaptation costs, e.g. Kemfert (2006). Sectoral adaptation costs e.g. coastal in Bosello et al (2011).	Captures cross-sectoral, market linkages in economy wide models (e.g. global, regional or national), including autonomous market adaptation and global trade effects.	Utilises aggregated representation of impacts and adaptation, no technical detail, no consideration of uncertainty. Omits non-market effects. Not suitable on its own for detailed national or sectoral-based planning.
Impact assessment (scenario based)	Projected future physical impacts and associated costs derived using climate models and sectoral impact functions/models, with comparison of costs and benefits of adaptation options.	Global scale, e.g. World Bank EACC (2010) and European scale (e.g. Watkiss et al. for a wider range of sectors (2011). National sector specific scale (e.g. UK Flooding (Evans et. al. 2004).	Sector specific analysis at regional, national or sub-national scale. Provides physical impacts as well as welfare values. Can capture non-market sectors.	Not able to represent cross-sectoral, economy-wide effects. Tends to treat adaptation as a menu of hard (engineering-) options to respond to specific defined scenarios. Medium to long-term focus of impact assessment may mean less relevance for short-term policy.
Impact assessment – extreme weather events. Risk assessment.	Variation of IA above, using historic damage-loss relationships from extreme events applied to future. Adaptation costs for replacement expenditures or analysis of response options. Risk based variations include probabilistic analysis and thresholds.	Sub-national and sector applications, e.g. – OECD (2009); EAC study (2009). Widely applied in flood risk management analysis with cost-effectiveness for defined levels of protection.	Allow consideration of future climate variability, in addition to future trends. Provides information on short-term priorities (associated with current climate extremes). As above, but risk based context allows greater consideration of risk and uncertainty.	May be inappropriate to apply historical relationships to future socio-economic conditions. Robustness limited by the current high uncertainty in predicting future extremes. Risk based approach introduces extra dimension of complexity with probabilistic approach.
Impact assessment - econometric based	Variation of IA above. Historical relationships of economic production and climate parameters using econometric analysis applied to future scenarios	Often applied at the national sector level, notably for agriculture	Can provide information on economic growth and allow analysis of longer-term effects. Provide greater sophistication with level of detail.	Mostly focused on autonomous or non-specified adaptation. Very simplistic relationships to represent complex parameters. No information on specific attributes.
Adaptation assessments	Economic analysis of adaptive management (including adaptive capacity and iterative (dynamic) adaptation pathway).	National scale methods and applications emerging (e.g. Hunt and Watkiss, 2011) and some sectoral applications for coastal floods (EA, 2010).	Stronger focus on immediate adaptation policy needs and decision making under uncertainty and greater consideration of diversity of adaptation (including soft options) and adaptive capacity.	Resource intensive analysis.

ClimateCost

ClimateCost (The Full Cost of Climate Change) is a European Commission RTD, 7th Framework Programme project, assessing the economics of climate change.

ClimateCost tasks

1. Identify and develop consistent scenarios for climate change and socio-economic development, including mitigation scenarios.
2. Quantify in physical terms, and value as economic costs, the effects of future climate change (the 'costs of inaction') under different scenarios for the EU and other major negotiator countries (China, India). This analysis will be at a disaggregated level, undertaken, where possible using spatial analysis (Geographic Information Systems, GIS). The analysis will include market and non-market sectors (coasts, health, ecosystems, energy, water and infrastructure). The analysis will also quantify and value the costs and 'benefits' of adaptation.
3. Assess the potential physical effects and economic costs of major catastrophic events and major socially contingent effects.
4. Update the mitigation costs of greenhouse gas (GHG) emissions reductions, consistent with medium- and long-term reduction targets/ stabilisation goals for the mitigation scenarios, including (induced) technological change, non-CO_2 GHG and sinks, and recent abatement technologies.
5. Quantify the ancillary air-quality co-benefits (in physical and economic terms) of mitigation, using a spatially detailed disaggregated approach to quantify benefits in Europe, China and India.
6. Develop and apply a number of General Circulation Models (GCMs) and Integrated Assessment Models (IAM) to integrate the analyses.
7. Bring the information together to provide policy relevant output, including undertaking analysis of policy scenarios.

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Further information

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