Chapter 12
A Precauctionary Strategy to Avoid Dangerous Climate Change is Affordable: 12 Reasons

Jeroen C.J.M. van den Bergh

Abstract There is a widespread sense that a sufficiently stringent climate mitigation policy, that is, a considerable reduction of greenhouse gas emissions to avoid extreme climate change, will come with very high economic costs for society. This is supported by many cost–benefit analyses (CBA) and policy cost assessments of climate policy. All of these, nevertheless, are based on debatable assumptions. This paper will argue instead that safe climate policy is not excessively expensive and is indeed cheaper than suggested by most current studies. To this end, climate CBA and policy cost assessments are critically evaluated, and as a replacement 12 complementary perspectives on the cost of climate policy are offered.

Keywords Climate change • Policy • CBA • Integrated assessment models • Social cost of carbon • Solar energy • Happiness

12.1 Introduction

It is generally felt that a climate policy which stabilizes atmospheric concentrations of greenhouse gases (GHGs) at a 'safe' level will be extremely expensive, whether measured in terms of monetary costs, reduced GDP growth or forgone welfare. This

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is supported by a number of influential economic cost–benefit analyses of climate policy as reviewed in Kelly and Kolstad (1999) and Tol (2008a, b). In this paper it will be argued that the application of cost–benefit analysis (CBA) to climate change and policy should be judged as being overly ambitious. To avoid the many fundamental and practical problems associated with CBA and the associated notion of 'optimal' climate policy, it will be argued that a better option is to adopt a more modest and practical approach, namely examining the cost of a safe climate policy. This reflects a policy aimed at a stable and safe level of atmospheric GHG concentrations—thus focusing on mitigation, not adaptation. The combination of risk aversion, pervasive uncertainty, and extreme climate change and events motivates such a safe or precautionary approach as a rational alternative to an optimal climate policy. In fact, (avoiding) extreme climate change may be regarded as the ultimate reason for us to worry about and respond to climate change. Even two strong advocates of using CBA to analyze climate change, Tol and Yohe (2007, pp. 153–154), state: "A cost–benefit analysis cannot be the whole argument for abatement. Uncertainty, equity, and responsibility are other, perhaps better reasons to act."

It will be argued here that the cost of climate policy has so far been approached from too narrow a perspective. This will involve a discussion of fundamental problems associated with applying CBA to climate change and policy. Spash (2007) concludes that cost-effectiveness studies are not much better than CBA's. Indeed, studies attempting to assess the monetary cost of climate policy make many debatable assumptions as well. Nevertheless, the shortcomings are less serious than in the case of climate CBA studies because the monetization of climate damage is avoided. Since some of the shortcomings of CBA's and cost assessments of climate policy cannot be resolved, one cannot hope for a single model analysis of climate policy to provide the definite insight about its cost let alone its optimality.

This paper will therefore offer an alternative approach consisting of assessments of the cost of climate policy from a range of complementary perspectives. Together, these aim to avoid or surpass the limits of existing CBA and policy cost studies. The alternative approach can be seen as trying to determine the economic and social costs of a safe or reasonably safe—given all sorts of uncertainties involved—climate policy by considering a range of perspectives to somehow bound the "cost space". The focus on a safe or precautionary climate mitigation policy can be regarded as the outcome of a qualitative risk analysis, as will be discussed in Sect. 12.3. Twelve perspectives on the cost of climate policy are offered. Together they deliver quite an optimistic conclusion, namely that climate policy is not excessively expensive and is certainly cheaper than suggested by most current studies. In other words, our global society can afford to invest in a safe climate policy. This should serve as relevant information for all politicians who fear severe economic consequences from stringent regulation of GHG emissions.

The remainder of this article is organized as follows. Section 12.2 briefly argues the failure of cost–benefit analysis of climate policy. Section 12.3 presents the main arguments in favor of a safe, precautionary approach to climate policy. Given that the current economic approaches to assessing the (net) costs of climate policy have severe limitations, they are prone to generating inaccurate estimates. This means there is a need for an alternative approach, as offered in Sect. 12.4. It presents the new approach consisting of 12 perspectives on, and interpretations of, climate policy costs that move beyond current model assumptions and limitations. Section 12.5 provides conclusions.

12.2 The Failure of Cost–Benefit Analyses of Climate Policy

The history of climate CBA shows enormous variation in estimates. For example, whereas early studies (e.g., Nordhaus 1991) excluded adaptation to and benefits of climate change, later studies did take them into account and arrived at lower climate damage costs. Despite variation, most climate CBA studies share many basic assumptions. These have received considerable criticism, much of which is difficult to resolve (e.g., Ayres and Walters 1991; Broome 1992; Barker 1996; Azar 1998; Neumayer 1999; Spash 2002; DeCanio 2003; van den Bergh 2004; Padilla 2004; Gowdy 2008; Tol 2008b; Ackerman et al. 2009; and various responses to the Stern Review). Criticism has been directed, among others, at the assumed behavior of economic agents, the social welfare objective used, the treatment of small-probability-high-impact scenarios, discounting and social discount rate values, monetary valuation of a human life, and the neglect or incomplete treatment of certain cost categories.

A main criticism is that the analysis of climate policy should not be conceptualized as a problem suitable for quantitative cost–benefit analysis but as one of risk analysis, since the cost of climate damage cannot be assessed with any acceptable degree of certainty. Weitzman (2007, p. 703) says about this: “The basic issue here is that spending money to slow global warming should perhaps not be conceptualized primarily as being about consumption smoothing as much as being about how much insurance to buy to offset the small chance of a ruinous catastrophe that is difficult to compensate by ordinary savings.” The latter means that social welfare losses due to extreme climate change cannot be reversed or undone through adaptation. Especially the treatment of extreme climate change and climate events characterized by a combination of small probabilities and large impacts has been argued to not go together well with an expected value approach to cost–benefit analysis. This view is the motivation for the approach adopted in this paper, namely an assessment of the cost of a (reasonably) safe climate policy. This specific, fundamental criticism is addressed in more detail in Sect. 12.3, which will result in an extended argument in favor of a precautionary approach to climate mitigation policy.

Perhaps the most important shortcoming of current economic studies of climate policy relying on CBA is that they incompletely account for extreme and irreversible climate scenarios, such as: extreme low or high temperatures; a slow-down or halting of the global thermohaline circulation, of which the Gulf Stream is a part; an extreme increase of the world’s mean sea-level over centuries due to the collapse of the ice sheets on Greenland and West Antarctica; ‘runaway dynamics’ caused by positive feedback mechanisms in the biosphere, such as substantial emissions of methane (with a much higher warming potential than CO2) from permafrost regions; changes in climate subsystems such as the 'El Niño Southern Oscillation'; acidification of the oceans due to high atmospheric CO2 concentrations, meaning a deterioration in the living conditions for marine organisms with yet unforeseen effects; and extreme weather events, notably extreme rainfall, an increased probability of heat waves and droughts, and an increased intensity of hurricanes due to warmer seas. If, moreover, such changes take place rapidly, then insufficient time for adaptation will contribute to higher damage costs. The omission of these extremities from CBAs is incomprehensible given that the ultimate reason for studying climate change is—or in any case should be—a concern for extreme events which will fundamentally alter the environmental conditions for humans and the rest of the biosphere. In fact, studies that have incompletely taken into account extreme events should not be taken too seriously—they really involve nothing more than toy models—and the respective authors should be modest about the policy implications of their analyses (see also Azar and Lindgren 2003). In particular, studies omitting extreme events will underestimate the cost of climate change, or the benefits of climate policy, and therefore be biased against safe climate policy. The problem is, of course, that most worst-case climate change scenarios cannot be accurately quantified.

The differential treatment of extreme climate events offers one explanation for the wide range of damage cost estimates of GHG emissions that one can find in the literature (Tol 2005; Fisher and Morgenstern 2006). Tol (2008a) performs a meta-analysis of them, suggesting that the most reliable estimate cannot be the outliers,thus explicitly questioning the high damage estimates used in the Stern Review. However, a meta-analysis assumes that all studies are equally valuable unless one weights studies, for instance, by giving a relatively high weight to more recent studies using updated information. But since Tol does not apply such a weighting scheme, the outcome of his analysis is dominated by the large share of (older) studies which neglect or incompletely address extreme climate change scenarios and events. The meta-analysis thus hides the fundamental shortcomings of the primary studies, even though it gives the impression of being an objective aggregation. An aggregation based on accounting for four shortcomings of previous studies leads to a lower bound to the social cost of CO_2 emissions equal to $125 (van den Bergh and Botzen 2014).

Other limitations and weaknesses of CBAs of climate policy have been well documented. Tol (2008b) lists the many imperfections in a refreshingly critical and honest account of climate damage cost studies.[1] In particular, he notes the neglect in existing studies of the impact of climate change on human conflict, large-scale biodiversity loss, economic development, and human population/demography. Most models take immediate adaptation for granted by assuming rational behavior by

[1] What is disappointing, though, is that after listing an impressive number of uncertainties andmissing elements in existing cost studies and presenting a range of marginal carbon cost estimates as wide as $20–669/tC (Tol 2008b, Table 2), Tol proposes to use a carbon tax in the lower range of $26–50/tC.

economic agents. A general shortcoming is the neglect of any impacts beyond 2100 in many studies.

Next, over long-term horizons, such as in climate change analysis, CBA is extremely sensitive to discounting and particularly the choice of (social) discount rate. A large part of the variation in results of studies that have undertaken a quantitative CBA of climate policy is due to this discount rate sensitivity. The debate on intergenerational discount rates was revived by the Stern Review (Stern et al. 2006). There are several fundamental objections to be made against discounting as formalized in the famous Ramsey formula, as well as objections against the choice of parameter values in applying this formula in climate change studies. For overviews of the various arguments see Dasgupta (2007), Quiggin (2008), Ackerman et al. (2009), and van den Bergh (2010, Section 2). A concise review and evaluation is in van den Bergh and Botzen (2014) who conclude that the arguments in favor of low discount rates outnumber and are more convincing than those in favor of high rates. They also argue that using a high discount rate effectively means giving little attention to low-probability, high-impact scenarios as these tend to involve extreme events far away in time. Most importantly, perhaps, as noted by Arrow (2007), even with a much higher social discount rate than the one resulting from the Stern Review's assumptions, and well above the value range accepted by most economists (3–6 %), the cost–benefit argument for stringent climate policy remains valid. Dominant researchers in the field as Nordhaus (DICE model) and Tol (FUND model) do not give much credit to fundamental objections against social time preference discounting and instead harshly judge the Stern Review as representing a "decidedly-minority paternalistic view", "lowest bound of just about any economist's best-guess range" and "nonconventional assumptions that go so strongly against mainstream economics". However, speaking of mainstream economics in relation to climate policy analysis does not do justice to the fundamental criticism of the suitability of CBA as a method to evaluate climate policies, as summarized above. One can indeed interpret fierce attacks on the Stern Review as a "historical accident", to use a term from the literature on path-dependence: if Cline (1992) and Stern had been the dominant players in the field, those arriving late on the scene and wanting to use high discount rates would have likely received fierce criticism for making unorthodox assumptions.

CBA is an attractive and reasonable evaluation method for well-bounded problems (local, sectoral) with limited time horizons, non-extreme and manageable uncertainties, reversible scenarios, and limited income inequality. But its application to global, long-term climate change and policy questions runs into severe problems.[2] Here CBA is not merely stretched to its extreme but breaks down. This does not mean that one has to reject qualitative-type of CBA thinking. Indeed, it is diffi-

[2] Notice that application of CBA to acid rain and related SO2 and NOx emissions reduction policies has not received so much attention, even though this problem is more limited in scope than climate change and policy. The economic research on acid rain has been dominated by cost-effectiveness analysis, with RAINS developed at IIASA probably being the best-known study of this type (Alcamo et al. 1990).

cult to escape thinking in terms of trade-offs between qualitative costs or the disadvantages and benefits or advantages of any choice. Such a qualitative, conceptual approach is in fact needed to support a precautionary approach to climate policy (van den Bergh 2004). But unlike the quantitative CBA approach, its qualitative counterpart expresses clearly that specific, detailed statements about the social optimality of choices in the context of climate policy are very, and possibly overly ambitious.

12.3 Arguments for a Safe, Precautionary Approach to Climate Policy

If it can be argued that a safe climate policy means considerably lower net costs than the absence of such a policy, it is rational to be in favor of such a policy. This represents a kind of cost-effectiveness combined with precaution, given the uncertainties involved, aimed at avoiding extreme damage costs due to climate change. As a guide we can take Nordhaus and Boyer (2000) estimate of 10 % and the Stern Review's estimate of almost 20 % potential GDP damage cost of extreme climate change (Stern et al. 2006). As noted in Sect. 12.2, considerably lower damage costs require the omission of relevant extreme climate events and scenarios. If we compare these figures with climate policy cost estimates by IPCC (2007), which are in the range of 1–4 % of global GDP, then safe climate policy is clearly seen to be socially efficient. The slogan used by some environmental NGOs is surprisingly appropriate: 'the most expensive climate policy is doing nothing'.

The combination of small probabilities and large impacts associated with extreme climate change and climate events does not go together well with an expected value approach to cost–benefit analysis, and moreover does not reflect the way humans generally tend to evaluate such problems (Botzen and van den Bergh 2009; Quiggin 2008). This can partly be understood through different treatments of risk aversion in expected and non-expected utility approaches. Low-probability, high-impact scenarios have a small expected value compared to more certain changes associated with less extreme costs, and as a consequence receive a relatively low weight in CBA analysis. This effectively means a risk-neutral or riskloving approach. Nevertheless, one may perceive such costs as very undesirable and hence place a considerable value on preventing low-probability, high-impact events from occurring, especially when such events are irreversible and involve the loss of non-substitutable goods or services, as is the case with climate change.

In line with this view, Loulou and Kanudia (1999) and van den Bergh (2004) have proposed studying climate change using a precautionary principle formalized via a minmax regret goal. This represents more risk aversion than an expected value approach and less risk aversion than, for example, maximin net benefits.

Tol (2008b, p. 10), a fervent believer in climate CBA, supports the precautionary approach to climate policy evaluation implicitly by stating that in view of the strongly right-skewed distribution of climate change damage costs (median \$14/tC, mean \$93/Tc, 95 percentile \$350/tC; Tol 2005): "The policy implication is that emission reduction should err on the ambitious side". Dietz et al. (2007, p. 250) make a convincing plea for precaution in climate policy as well: "Those who deny the importance of strong and early action should explicitly propose at least one of three arguments: (1) there are no serious risks; (2) we can adapt successfully to whatever comes our way, however big the changes; (3) the future is of little importance. The first is absurd, the second reckless, and the third unethical."

Environmental economists have long thought about uncertainty, irreversibility and precaution, which has given rise to option value theory. But surprisingly they have refrained from systematically applying it to the most relevant case of irreversible environmental change, namely climate change (an exception is Schimmelpfennig 1995). In brief, this would mean that the foregone benefits of a certain 'preservation scenario' (i.e. safe climate policy) are included as a cost category of the 'development scenario' (i.e. no policy, leading to climate change). The resulting option value can be interpreted as the value of flexibility to either accept climate change at a later date or not, where the flexibility is due to investing in GHG emissions reduction to avoid the irreversible build-up of greenhouse gases in the atmosphere. Ha-Duong (1998) applies the notion of quasi-option to climate policy, which states that precaution allows for learning about climate change in terms of risks, costs, and adaptation opportunities. Admittedly, a main weakness of applying (quasi-)option value theory to climate change policy is that it takes expected utility theory as a basis, which, as argued above, is problematic in view of the low-probability, high-impact scenarios associated with climate change.[3]

Gollier et al. (2000) have shown the precautionary principle to result from a rational decision formalized as dynamic optimization under uncertainty and irreversibility involving Bayesian updating/learning. The conditions for precautionary action turn out to depend on risk aversion and "prudence". The latter is captured by the third derivative of the utility function and reflects the degree to which an individual increases his savings in response to an increase in uncertainty about future revenues (Kimball 1990). Other approaches than expected utility maximization and minimax regret to support a precautionary policy are maximin utility and nonlinear methods like prospect theory or rank-dependent utility theory, which one can characterize either as rational or boundedly rational (but not irrational) approaches. Although experts seem not to entirely agree on the best theoretical approach to address decisions in the face of low-probability, high-impact scenarios, a defensible

[3] Several authors have theoretically studied climate policy given economic (investment) irreversibilities. They conclude that there is then a risk of overinvestment in economic capital (manufactured and human) and that current emissions reduction policy should be slightly laxer than without learning (Kolstad 1996; Ulph and Ulph 1997). However, these findings do not suggest a move away from precaution, since climate irreversibility is characterized by much more extended time scales than economic irreversibility, while for climate capital, unlike for economic capital, no substitutes are available. These studies can also be criticized for employing an expected utility approach.

approach seems to be to give relatively more attention or weight to extreme case scenarios, which comes down to a kind of minimax regret approach.

In the face of extreme uncertainty a quantitative analysis will not necessarily be able to offer more informative insight than a mere qualitative analysis. The reason is that the extreme uncertainty does not disappear by adding more quantitative sophistication to the method of analysis or by reducing uncertainty to (subjective) risk. All existing models that include uncertainty somehow apply arbitrary probability distributions to extreme climate events and changes (surveyed by van den Bergh 2004). These models regard investments in emissions reduction as a decision on risky investments, but they insufficiently reflect the irreversibility of climate change, the extreme uncertainty (content and likelihood) associated with certain scenarios and events, and the non-insurability against extreme climate change and events due to risks being highly correlated for all regions in the world.

A somewhat different way to understand the rationale behind a precautionary approach to climate policy is based on comparing the likelihood and features of climate and economic instability. This represents a kind of risk management view, which conceptualizes climate policy as the outcome of a trade-off between the risks and costs associated with natural and economic instabilities. However, these two risks are neither on equal par nor symmetric. One may even go as far as to say they are of a different order and thus simply incomparable. This can be reasoned as follows. With a given global environment under a stringent climate policy, humans cannot predict economic changes with certainty, but they can guide and control them within boundaries. Economic stability can then be maintained. For example, if a stringent climate policy turns out to create too high economic costs and too much instability, the policy may be altered or adapted. However, under extreme climate change—due to a lax or lacking climate policy—one has to reckon with macro-scale risks, with catastrophic and irreversible changes in the coupled climate-biosphere system which cannot be controlled by any public policy, even though impacts may in some cases be ameliorated by climate adaptation policies. Governments will then be unable to avoid extreme impacts on the world economy, and economic policy will have a very hard time stabilizing economic responses to extreme climate change. In fact, a severe climate crisis may very well stimulate an unprecedented economic crisis. All in all, economic adaptation and policy under stable natural, climate conditions, enhanced by a stringent climate policy, are easier and safer than responding to unstable natural conditions resulting from a lax climate policy. This is consistent with the view of Azar and Schneider (2003, p. 331): “Thus, we do not see costs and benefits in a symmetrical cost–benefit logic, but rather as an equity problem and a risk management dilemma.” The Stern Review also shares this standpoint, and many other observers have made similar statements.

The extensive literature on resilience and ecosystem functioning also suggests that we should be extremely careful in tinkering with the biosphere through humaninduced climate change, as this may cause discrete, structural changes in all kinds of ecosystems (freshwater, marine, rangeland, wetland, forest, arctic) when certain critical thresholds of GHG concentration in the atmosphere are surpassed (Holling 1986). The risk of extreme events or disasters, as documented in Sect. 12.2, is relevant here, as many of them will considerably affect basic conditions for many ecosystems. In addition, the uncertain synergy between biodiversity loss and climate change is relevant. Biodiversity supports the stability of ecosystem functions and related services to humans, while biodiversity loss is being enhanced by climate change. Against this background, some have even denied the relevance of normal scientific analyses of complex issues like climate change and climate policy on the basis of the climate system being complex and able to show catastrophic behavior (Rind 1999). Add to this the other dimensions of global change that may interact with climate change in nonlinear and unknown ways, such as land use, deforestation, water use, destruction of wetlands, acid rain, acidification of the oceans, and human control over a sizeable portion of primary production. Complexity implies that causal connections between a multitude of potential factors and effects cannot be identified, let alone be quantified. Against this background, a 'post-normal science' has been pleaded for, characterized by "uncertain facts, values in dispute, high stakes and urgent decisions" (Funtowicz and Ravetz 1993). The climate problem meets all four characteristics.

The foregoing set of considerations suggests that the implementation of a precautionary principle in climate policy emerges as a rational strategy. Neither decisionmaking based on quantitative CBA nor waiting until more information is available are convincing strategies. An often-heard argument against the precautionary principle is that climate policy means that alternative public goals have to be sacrificed. But whereas, for instance, less health care and education can indeed reduce growth and welfare, they are unlikely to cause extreme and discrete changes at a global scale. For this reason, climate policy needs to be treated as fundamentally different from many other areas of public policy.

Finally, Van den Bergh (2010) discusses the more modest cost (so no full CBA) assessment studies of a safe climate policy and reviews the methods and assumptions that have been used to produce the main cost estimates. Because of lack of space, we refer here to the original article (Sect. 12.4).

12.4 Twelve Reasons Why a Safe Climate Policy Is Affordable

The section below presents 12 new, complementary perspectives on the cost of climate policy.

12.4.1 Perspective 1: Extrapolating Learning Curves for Renewable Energy

The easiest way to reason about the cost of climate policy is by considering a most likely definite solution to the core problem, that is, the emission of greenhouse gases, notably carbon dioxide. Renewable energy really offers the only definite solution, as it can in principle support the supply of electricity and other types of energy carriers in a carbon-free way. Moreover, from the perspective of rebound risks, indirect energy use due to energy conservation or efficiency improvements (Sorrell 2007), renewable energy has a major advantage over energy conservation. Van den Bergh (2010) argues why within this category solar photovoltaics (PV) is a main candidates for future dominance.

van der Zwaan and Rabl (2003, 2004) have analyzed scenarios of the price and cost of solar PV on the basis of experience or learning curves. Such curves convey that overall production costs tend to decline with an increase in cumulative production. It is true that overall costs not only capture learning and innovation (R&D) effects but also change in market prices of inputs (notably material inputs). The latter may sometime increase which can (temporarily) reverse the normal, negative relation between cumulative production and costs. Nevertheless, generally speaking learning curves are seen as quite a robust tool to examine the long-run cost behavior of technologies. For solar photovoltaic (PV) energy, a most likely or middle scenario delivers an estimate on an order of magnitude equal to US$60 billion associated with a cumulative production of about 150 GWp (note: in 2004 cumulative production was about 1 GWp). This amount of money represents an extra expenditure over the investment in fossil fuel electricity, which is needed to make solar PV competitive with electricity produced from fossil fuels (van der Zwaan and Rabl 2004, Table 2, progress ratio 0.8). If learning is favorable, then US$30 billion (at 50 GWp) is a better estimate, while if learning is slow the cost may rise to US$300 billion (at 1000 GWp).

12.4.2 Perspective 2: Global Climate Policy Cost Normalized by OECD GDP

Here the cost of worldwide climate policy will be normalized by the GDP of OECD countries. This can be justified on the basis of their historical contribution to climate change (Botzen et al. 2008) as well as their currently high incomes relative to the rest of the world, i.e. historical and intra-generational fairness. We can then take the range of 1–4 % suggested by a survey of studies by IPCC (2007) as one basis for a climate policy cost estimate. The second estimate can be drawn from the previous section, where the cost of public support to make solar PV competitive was estimated to be in the range of US$30 billion to US$300 billion with a best, middle estimate of US$60 billion. These costs result in only 0.17 % (with an uncertainty range of 0.08–1.65 %) of the joint GDP of the 30 OECD countries in 2007 (which was US$ 36,316 billion; OECD 2008). An equal distribution would simply come down to 60/30 = US$2 billion per country, which is not a shocking figure. If the investment were spread over the course of 10 years, then it would amount to only US$200 million per country per year (over 10 years) or on average 0.017 % of GDP (with an uncertainty range of 0.008–0.17 %). In the worst case scenario, this would imply a cost to a family with a net income of €25,000 about €40; in the most likely case this would be €4, and in the most favorable case €2, over a 10-year period.

In 2007, OECD income was about 55 % of world GDP (about US$66 trillion). If OECD would carry all the cost of climate policy, and taking the climate policy cost range identified by IPCC (1–4 %), this would lead to an average cost for OECD countries equal to 1.8–7 % of GDP. This is significantly higher than the estimates based on public support of solar PV. Why is that so? First, the 4 % is quite a high estimate, and it is likely that the 1 % estimate is a more reasonable order of magnitude, yielding 1.8 % for the OECD countries. This is, however, still about 100 times larger than the yearly middle estimate and ten times the yearly upper endestimate (assuming a 10-year investment period to make solar PV competitive) of the cost of public support of solar PV. One important reason is that climate policy initially will indeed be more expensive as solar PV is still maturing, meaning that it can not make a significant contribution to reducing GHG emissions. However, according to the scenario sketched under perspective 1 in Sect. 12.5, after a 10-year period solar PV should fairly quickly take over the market and provide the major means of reducing GHG.

Therefore, during the first 10 years one should expect a relatively high cost of 1.8 % and subsequently a rapid drop in the cost of climate policy to 0.017 % (with an uncertainty range of 0.008–0.17 %). This pattern should not come as a surprise, as it simply reflects an initial investment in R&DDD and then enjoying the returns on this investment. This is consistent with the suggestion by Sandén and Azar (2005) that we need to enter a decade of experimentation with low carbon technologies.

12.4.3 Perspective 3: Delayed GDP Growth

If it is true that climate policy will cost about 1 % of GDP per year, then given that economic growth in many countries has historically been around 2 % on average, and in some countries higher, this would mean that net growth, after discounting the cost of climate policy, would still be positive, and that one would reach a certain level of income with a delay.

A related perspective on the cost of climate policy was proposed by Azar and Schneider (2002). They take as a starting point studies suggesting that the absolute cost of reaching what is regarded by the IPCC as "safe" concentrations of CO2 is in the range of 1–20 trillion US$. Although this may seem impressive, it turns out to imply only a few, namely 1–3, years' delay in achieving a specific level of income in the distant future. The delay evidently depends on income growth. Global income during the twenty-first century is expected to increase about tenfold (on average 2.35 % per annum). Azar and Schneider (2002, p. 77) calculate that "if the cost by the year 2001 is as high as 6 % of global GDP and income growth is 2 % per year, then the delay time is 3 years. . .". This 3-year delay is moreover easily dominated by random noise given the uncertainties involved in GDP movements over a period of one century. That is, uncertainty over such a long time horizon might translate in a variation of the final GDP level (i.e. after one century) which exceeds the 6% figure. This all means there is little reason to worry about the long-term negative effects of climate policy on the economy. In other words, seen in a long-term perspective, the costs of a stringent climate policy are marginal in economic terms. Aznar and Schneider further note that "…the global economy is expected to be an order of magnitude larger by the end of this century…we would still be expected to be some five times richer on a per capita basis than at present, almost regardless of the stabilization target."

12.4.4 Perspective 4: Happiness Instead of GDP

Economic evaluation of climate policy is often cast in terms of lost GDP. This seems attractive, as the economic and welfare impact is captured in a simple, aggregate number. However, it neglects that implicit assumptions and judgments about the relationship between wellbeing, happiness, and GDP have been strongly criticized (van den Bergh 2009), from the angles of inequity, lexicographic needs, informal activities and environmental degradation. This has given rise to questioning the use of indicators like income and GDP as proxies for social welfare and progress. There is much support for the view that beyond a certain threshold, which has been passed by most rich countries, average income increases do not translate in significant rises in well-being. In particular, this research indicates that somewhere between 1950 and 1970, the increase in welfare stagnated or even reversed into a negative trend in most industrials (OECD) countries, in spite of steady GDP growth, the so-called "Easterlin Paradox" (Easterlin 1974). This supported by the 'Eurobarometer surveys', the half-yearly opinion polls of the inhabitants of the EU member states, as well as by aggregate indicators of sustainable income based on GDP corrections, notably the ISEW and (derived) GPI indicators (Lawn and Clarke 2008). Of course, one should not expect a rigid threshold to apply generally for all countries, cultures, and times. A country comparison clarifies that happiness is characterized by diminishing returns on increases in GDP per capita. This means, not surprisingly, that for poor, developing countries the correlation of income and well-being is higher than for rich countries.

Three stylized facts assessed by happiness research can explain the observed delinking of income and happiness (van Praag and Ferrer-i-Carbonell 2004). First, income and income growth contribute considerably to happiness if people are poor or countries are in a low development phase, as extra income will be mainly spent on basic needs. Second, although people may enjoy short-term or transitory increased happiness effects, ultimately they will adapt or get used to a higher income and changed circumstances in various other dimensions. One explanation for this is that our senses can only handle a limited amount of stimuli, and ultimately satisfaction or boredom ensues. Since most people are not aware of the phenomenon of adaptation, they continue striving for 'more'. This is reflected by a range of terms used by different researchers: 'addiction', 'hedonic adaptation', 'hedonic treadmill', and 'preference drift'. Third, people compare their situation with that of others in a peer group, so their welfare has a relative component. This is associated with status-seeking and rivalry in consumption. In addition, studies have consistently found that income-independent factors greatly influence individual welfare or happiness, the most important ones being health, having a stable family (partner, children), personal freedom (political system), and being employed. Certain studies reported below also point out the relevance of environmental and climate factors

The implication of the foregoing stylized facts is that absolute individual income at best imperfectly, and beyond a certain threshold hardly, correlates with individual welfare (Clark et al. 2008). Relative income turns out to be critical. But at the societal level, relative income changes are largely a zero-sum game: what one wins another loses.

Therefore, using effects on happiness instead of GDP as a criterion for judging climate policy is likely to provide quite different conclusions. Three considerations are relevant here. First, although climate policy may lead to a slower pace of economic growth, the foregoing discussion suggests that this translates into a smaller or even insignificant loss in happiness terms, depending on which country or group of people is considered. Secondly, climate policy aimed at preventing extreme events implies avoidance of serious reductions in happiness, given that happiness directly depends on climate, i.e. it involves direct non-market effects on individuals and households. This means that the economic and welfare effects of climate change measured in GDP terms may underestimate the real impact on happiness. Especially extreme climate events are not easily captured by GDP or other monetary cost terms, as argued in Sect. 12.2. Extreme climate change will have a profound impact on local and regional sea levels, temperatures, and weather patterns. This can in turn cause extreme effects on resource availability (notably clean water), human health, human security, vulnerability of poor people in regions with low productivity (Sahel countries), migration, and violent conflicts. It is virtually impossible to cost-account for these, even though it is clear that human happiness and basic needs are then seriously at stake. Third, although climate change may not affect the happiness of people in Western countries much, for people in poor countries it may mean that their basic needs will come under threat, which is likely to create severe and structural losses in happiness. In addition, richer people and richer countries can more easily adapt to climate change so that they can restore or approximate their old happiness levels. This is because rich countries are characterized by high levels of wealth (financial reserves), high average education, good access to modern technologies, and a generally high capacity for collective action.

Although no serious climate policy study has employed a happiness type of criterion or goal, a few studies have examined the impact of climate conditions on happiness. For example, Rehdanz and Maddison (2005) and Frijters and van Praag (1998) econometrically examines the relationship between temperature and happiness and find significant effects. The shortcoming of these an many other partial analyses is that they consider small temperature changes or differences and give no attention to large changes or even extreme climate change or events. As a result, these studies may deliver an overly optimistic and insufficiently representative general picture of how people's happiness responds to climate change.

Cohen and Vandenbergh (2008) consider the lessons that can be learned from happiness research for climate policy, focusing on consumers. Taxes on pollutive consumption with a positional good character has two benefits: it reduces the status externality due to reduced consumption of such goods (Ireland 2001), and it reduces the total pollution associated with the consumption. Layard (2005) suggests taxing income to stimulate leisure and temper "status games" with respect to income and consumption. This may reduce status effects and pollution related to goods consumption equally, although this will depend on the shift in consumption (e.g., more holidays to distant countries will give rise to increased air traffic with associated GHG emissions).[4]

A provision to the above arguments is that people may adapt to a changed climate in the sense of being initially (negatively) affected in their happiness, while later slowly recovering their old happiness level. However, such adaptation is difficult to imagine for extreme climate change and events. Finally, note that adopting a happiness approach may also affect the discount rate debate. The reason is that one would then be less inclined to discount as this would mean that the happiness of a person in the future would be valued less than that of a person living now. When more general, abstract notions like costs and benefits are employed instead, as in CBA studies, specific people and their happiness disappear from the picture, making the case for discounting easier to defend.

12.4.5 Perspective 5: Comparison With Large Public Investments: Iraq War, Financial Crisis, Military R&D and Sectoral Subsidies

The cost of climate policy or more particularly of making solar PV a competitive technology might be seen as a large public project. This suggests a comparison with other public projects. Two large 'projects' will be considered here, namely the Iraq war and combating the financial crisis. Van den Bergh (2010) also considered R&D investment in the military sector, and expenditures on subsidies to economic sectors.

Stiglitz and Bilmes (2008) have estimated the cost of the Iraq war to the United States to be at least US$3 trillion (3000 billion). Hartley (2006) notes that the economic costs of war receive far less attention than political, moral, legal and military

[4] The happiness perspective also affects the evaluation of other types of policies. Frank (1985), Ireland (2001) and Layard (2005) illustrate specific findings of happiness research as applied to economic policy: (extra) taxation of working overtime, (extra) taxes on status goods, limiting commercial advertising, and restricting flexible labor contracts. Although from a traditional economic growth perspective these look like bad measures, they are positively evaluated from a real welfare or happiness perspective.

considerations. He suggests that the US could have bribed Saddam Hussein by offering him and his family US$20 billion to leave Iraq, giving the Iraqi people US$50 billion, and on top of that save US$30 billion given that the cost of the war was ex ante (grossly under-) estimated at US$100 billion.

Another interesting comparison is with the financial crisis in 2008/2009. The USA decided overnight to reserve US$700 billion to stabilize the US banking system. Governments in Europe are likely to have reserved a similar amount. For example, The Netherlands created a €20 billion fund to stabilize the financial sector and he UK spent about €44 billion to take a majority share in four large British banks to rescue them. In total, OECD countries may have invested more than US$2 trillion (2000 billion) to stabilize the financial system. One may argue that some of the guarantees offered by countries in response to the financial crisis are in fact only creating reserves or represent investments in (shares of) banks rather than being effective spending, but nevertheless the countries or at least their governments were willing to set aside so much money in response to a threat without the support of any cost–benefit analysis

So governments worldwide have invested roughly US$5 trillion in the Iraq war and countering the financial crisis jointly. We can compare this with the range of climate policy cost estimates, i.e. 1–4 % of world GDP (US$66 trillion in 2007), or 0.7–2.7 trillion US$, which is only 14–54 % of the aforementioned public investments. If one focuses on the cost range of making solar PV competitive, i.e. US$30 billion to US$300 billion with a middle scenario estimate of US$60 billion (Perspective 1 in this section), then as a proportion of the current investments in Iraq and the financial crisis this comes down to a central estimate of about 1 % and a range of 0.6–6 %. In other words, if these percentages of current public investments would be diverted to renewable energy, we would very likely solve the problems of energy scarcity and climate change. If the cost of making solar PV competitive is compared only to the cost of the Iraq war, then the assessed central estimate of US$60 billion and the higher end estimate of US$300 billion result in only 2 % and a uncertainty range of 1–10 % of the expenditures on the Iraq war.

12.4.6 Perspective 6: The Current Cost of Energy Is Fairly Low

Here it is argued that current fossil fuel-based energy (gasoline and electricity) is cheap, too cheap in view of associated negative externalities. The latter is especially true if the cost of CO2 reflects extreme climate events and scenarios (van den Bergh and Botzen 2014).

The falling cost of energy in various areas can be observed by considering the share of energy cost in total national income. The ratio of (all) energy expenditures to GDP since the 1970s shows a pattern that starts at around 8 %, increases to about 14 % in the early 1980s and then drops again to levels below those of 1970 and recently increases again (EIA 2008). This illustrates that—in any case, until recently—the cost of energy can be judged as fairly low. Even though energy is the fundamental input to all human economic activity, roughly 90 % of income is spent on things other than energy. Moreover, continuous GDP growth and an almost constant share of energy costs in it suggest that the disposable income after energy expenditures has increased over time.

A disadvantage of the aggregate approach to measuring energy expenditures as a share of GDP is that it hides income inequality. Generally, low income families spend a larger part of their income on energy, and they will also see a relatively rapid increase in the cost share when energy prices rise. The shares can differ between low, middle, and high incomes from 15 %, 5 % and 2 %, respectively. This suggests that for some people, energy use may represent a considerable expenditure, while for many it does not. Roberts (2008) regards households as "undoubtedly fuel poor" when they are spending more than 10 % of their income on energy just to meet basic requirements. This 10 % threshold may reflect, however, that we take a very low share of energy cost in income for granted simply because this is a historical fact. Income inequality does suggest, though, that a serious climate policy raising energy prices might need to be complemented by an income redistribution policy (e.g., as part of shifting taxes from labor to energy).

Another indication that the cost of energy is not very high or even low is that the long-term average oil price (US crude oil prices adjusted for inflation in 2006 US$), if calculated from 1869 to 2007, equals $21.66 per barrel for world oil prices, and for the post-1970 period, $32.23 (http://www.wtrg.com/prices.htm). In addition, the sharp increase in the oil price in 2007–2008 did not give rise to serious, sustained social unrest. This all means that there is room for safe climate policy, which will undoubtedly increase the price of energy.

12.4.7 Perspective 7: Stimulating a Fundamental Social–Technical Transition

Climate change policy is not a simple, one-dimensional policy or an instrument with a clear cost, rather a complex process of multilevel and multi-dimensional change involving the unlocking of a dominant, undesirable system of fossil fuel technologies and infrastructures, and changing institutions, incentives, knowledge bases, and international cooperation. This is hoped to stimulate a "social-technical transition to sustainability", involving structural changes in the economy, including technological innovations and alterations in sector structure, demand side patterns, products types and designs, and institutional arrangements. Such qualitative changes are not well captured in one-dimensional monetary indicators, be it cost measures or foregone GDP growth.

Against this background, Prins and Rayner (2007) argue in favor of "placing investment in energy R&Don a wartime footing". Earlier, former US Vice-President and Nobel Peace laureate Al Gore made a similar call for a "global Marshall Plan". Various others have referred to the Manhattan Project and New Green Deal in this context. Sufficient R&D on de-carbonized energy technologies and a transition to sustainable energy technologies are indeed not guaranteed by environmental regulation alone. One important reason is the lock-in features of fossil fuel energy and related technologies like vehicles with combustion engines. Case studies of historical transitions show that a number of conditions need to be met for a transition to occur (Geels 2005). One of these is public investment in infrastructure and basic (fundamental) research. The history of nuclear fission shows this clearly; it received strong support through direct subsidies and military R&D (in the USA). Several other technologies have benefited greatly from public R&D, particularly investments in military R&D. Notable in this respect are information and communication technologies (ICT), supporting technologies like solid state electronics, semiconductors, transistors, integrated circuits, data transmission networks, and of course basic software codes. All these have received massive funding from the (American) military complex, usually with the motivation of the Cold War.

In many countries, agriculture also has received a great deal of public support, both to maintain the status quo (protection) and to foster certain transitions (Green revolution). For example, the post-war transition in Dutch agriculture was extensively funded by the government through investment subsidies, financial compensation for taking out land, public investment in land consolidation, and the creation and maintenance of drainage systems. This was motivated by a strong urge to achieve food security and self-sufficiency. Similarly, if one recognizes a stable climate as a basic condition for human life and activity, one needs to seriously invest in it.[5]

12.4.8 Perspective 8: Behavior, Learning and Substitution

Closely related to the previous transition perspective is a behavioral perspective. Many substitution opportunities at the level of inputs, sectors, and demand are insufficiently recognized by existing models because of aggregation and limits of empirical data. Notably, stringent climate policy will move prices outside ranges historically observed, so that, for instance, the empirical price elasticities of demand may underestimate potential responses. The more substitution opportunities exist, the easier it is for systems to adapt in a way so as to reach a similar performance level without much additional cost. Moreover, models often do not reflect the fact that in the long run people can change fundamental choices that affect their energy use, or the very many ways in which individuals can adapt to a higher energy cost. For instance, car users can adopt the following strategies: changing the time they drive (outside peak hours), carpooling, using other means of transport (walking,

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[5] I am grateful to Frank Geels for suggesting these examples.

biking, public transport), traveling less, being more efficient in combining trips, and in the longer run changing jobs or houses to reduce commuting distances.

A particular aspect of the behavior of firms and individuals is learning and innovation. Sagar and van der Zwaan (2006) examine learning-by-doing in relation to renewable energy and note various learning mechanisms: at the individual worker level (education, learning-by-operating so as to develop tacit skills), within a firm (learning-by-manufacturing), within the industry (learning by copying), across different industries, and within supply-demand interactions (learning-by-implementing, such as integrating PV systems into buildings, on roofs, which involves institutional structures such as for financing and equipment maintenance). Feedback from users to producers and from products to processes, along with systemic improvements (adjustment of all elements, such as institutions, markets, integrated building components, production chain) lead to falling overall costs of the renewable energy technology. Generally, the literature shows that adding endogeneity of growth, i.e. R&D or learning instead of exogenous technological change, reduces policy cost estimates (Söderholm 2007).

It is fair to add that some types of bounded rationality may lead to higher estimates for certain policy cost categories than the rational agent assumption. The energy gap literature illustrates this. Firms do not always invest in profitable energy conservation opportunities for various reasons. One is that agents do not have full information; another is that they do not minimize overall costs but instead focus on what they regard as main activities or investments, which does not include energy conservation; and habitual behavior has also been suggested as an explanation. Information provision and other strategies to stimulate more rational responses as part of climate policy may increase energy conservation (rebound effects not considered) and thus reduce the cost of effective policy. A good translation of insights from behavioral to environmental, energy, and climate economics is currently lacking and would be needed to shed more light on these issues (Brekke and Johansson-Stenman 2008).

12.4.9 Perspective 9: Ancillary Benefits

As discussed in Sect. 12.2, CBA studies of climate policy have omitted many benefits or avoided cost categories. The euphemistic term employed for some of these is ancillary benefits or co-benefits of policy. One that has received ample attention is that the reduction of GHGs generated by fossil fuel combustion will sometimes go along with reductions in other emissions, notably acidifying substances (nitrogen oxides and sulfur dioxide). For example, HEAL (2008) estimates that if the European Union raised its GHG emission target from the current 20–30 % (in line with IPCC recommendations), then additional co-benefits in the range of €6.5–25 billion per year would result from health savings arising from an associated reduction in emissions of fine particles, nitrogen oxide, and sulfur dioxide. All avoided cost categories in CBA studies of climate policy can be regarded as ancillary benefits. Van den Bergh and Botzen (2014) try to quantify these and arrive at a lower bound to the social cost of carbon (or CO_2 to be more precise).

The strong connection between scarce fossil fuel resources and greenhouse gas emissions from combusting fossil fuels also creates a relevant co-benefit. Notably, solving emissions problems by creating new sources of energy (renewable) will mean reducing problems of energy resource scarcity, avoiding potential fierce oil peak shocks, enhancing energy security, and avoiding conflicts over scarce energy resources. For example, a study assessing the social cost of the OPEC oil cartel to the US identified four cost categories, namely wealth transfer to OPEC, cost of strategic petroleum reserve, total GNP loss due to price shocks and shortages, and military costs. This resulted in an estimated cost ranging from about US$150 to 400 billion per year (1990$) during the period 1974–1985 (Green and Leiby 1993).

12.4.10 Perspective 10: Upward Bias in Ex Ante Estimates of Regulation Cost

Various studies indicate that there is often a gap and sometimes even a large gap between ex ante and ex post estimates of the costs of environmental regulation, including both private and public-administrative costs (Harrington et al. 1999). MacLeod et al. (2009) find this for a wide range of environmental policies in European countries, including policies aimed at water and air pollution, health, food safety, fuel standards, directives on combustion plants, and animal welfare. There are two important reasons why ex ante cost assessments may deliver overestimates. First, information on actual costs is often provided by firms having an interest or stake. As a result, those being regulated may provide overly high estimates of individual abatement costs. This can be due to strategic behavior to resist implementation of stringent regulations, or simply to individual uncertainty about (future) abatement costs. Standard environmental economics somehow recognizes these problems, regarding price regulation as having the advantage that it decentralizes the problem of environmental regulation, and not requiring governments to have full information about pollution abatement technologies and associated costs (Baumol and Oates 1988). A second reason for ex ante overestimates is that they may neglect or underrate the potential for reduction of abatement costs through polluters' innovation, learning, and adaptation (see van den Bergh 2010, Section 4).

12.4.11 Perspective 11: International Cooperation and Agreements

An additional important factor influencing cost estimates of climate policy is the presence (or absence) of international agreements, or more generally international cooperation between countries on climate policy and related technological diffusion. If international agreements are absent or weakly constrain individual countries, vast differences in policy may exist between countries. As a result, the costs of stringent climate policy for industries or consumers may be high since it will mean a loss in the international competitive position of industries as well as leakage of emissions from countries with stringent to those with less stringent policies. Instead, a stringent climate policy agreed upon by all countries in the world would mean a level playing field that reduces the policy cost, as competitive disadvantages and emission spillover is avoided. The relationship between policy cost and international cooperation is like a vicious circle. As long as governments think that the cost of safe climate policy is high, they will refrain from committing themselves to a stringent international climate agreement. However, as long as such an agreement is lacking, the cost of unilaterally stringent climate policy will be excessively high because of the loss of competitive position.

12.4.12 Perspective 12: Lack of Insurance Against Climate Change

Currently, private insurance with premiums that reflect the risk of extreme events like those possibly caused by climate change, such as flooding and hurricanes, is largely lacking in most countries (Botzen and van den Bergh 2008). This has three consequences for judging the cost of climate policy. First, it means that there is no efficient sharing of climate-related risks which would reduce the overall costs of the consequences of both climate change and climate policy. Second, the absence of insurance means that appropriate incentives for adequate adaptation to climate risks and changes is lacking. Third, it also means disoptimal incentives for stimulating producers, consumers, (re)insurance companies, and even governments to efficiently reduce greenhouse gas emissions. At present, insurers are already actively involved in promoting reductions in greenhouse gas emissions (Botzen et al. 2009). Such efforts are likely to become stronger if more climate change risks were covered through private insurance. Both insured and insurers have incentives to limit climate risk in case increases in the frequency and severity of natural hazards are reflected in a higher cost of offering insurance and higher premiums. Moreover, with insurance, adaptation at the individual and social level will be more adequate so that climate mitigation policy may need to be less stringent and thus less expensive. In other words, with adequate insurance arrangements in the face of climate-related risks, safe climate mitigation policies will turn out to be more efficient, i.e. less expensive. This is especially true since climate insurance would imply many indirect economic effects because insurance affects the direct and indirect costs of economic activities and therefore works as a price signal of risk. If climate policy is undertaken in the presence of adequate insurance arrangements for risks related to climate change, or if such a policy includes incentives for insurance companies to undertake these arrangements, then the cost of climate policy will be lower than without such arrangements.

12.5 Conclusions

This paper has argued that both cost–benefit analysis and cost assessment or accounting of climate policy using quantitative models are overly ambitious, despite the fact that we can evidently learn much from them. The multi-perspective approach to evaluating the cost of a safe, precautionary climate policy as presented here can be regarded as a way out of the never-ending debate on the usefulness and feasibility of cost–benefit analyses of climate policy. Indeed, if climate policy is seen as a precautionary strategy to avoid unpredictable and irreversible natural as well as economic catastrophes rather than as a way to optimize social welfare (or GDP growth) in the face of GHG emission–climate–economic damage feedback, then a focus on qualitative risk analysis and cost assessment of climate policy makes more sense than a quantitative cost–benefit analysis. This is true both for methodological reasons—CBA possibly represents an overly risk-loving decision-maker—and for practical reasons—quantification of extreme events with small probabilities simply is not feasible.

The paper has tried to credibly defend, using various arguments, that a safe or precautionary approach to climate policy is indeed rational. If one does not accept one argument: there are 11 others waiting in line. The set of 12 perspectives together provide a strong case for the view that a safe climate policy is likely to be affordable and cheaper than most previous studies have suggested.

The happiness or subjective well-being perspective on the cost of climate policy emerges as possibly the most important new view. It is pertinent to introduce it into the debate on climate policy to arrive at a correct picture of what we really gain and sacrifice if we undertake a stringent, safe climate policy worldwide. In terms of happiness or real welfare, climate policy looks much less expensive than in terms of lost GDP, while climate change was evaluated as much more expensive in terms of happiness than in terms of GDP.

Finally, on the basis of various quantitative indicators it was argued that energy is currently not very expensive, so there is considerable leeway for increasing its price through climate policy. Indeed, an effective and safe climate policy cannot avoid raising energy prices considerably, certainly if one wants to simultaneously minimize the rebound effects of energy conservation and efficiency improvements, restructure demand and supply in the economy in a sustainable direction, and stimulate a transition to renewable energy sources. In addition, one will need countervailing distributional measures to avoid energy poverty (e.g., recycling carbon tax revenues to low incomes, or block-pricing for carbon or energy). To keep promising but expensive energy technology paths open, technological subsidies (notably for R&D) will be needed as well.

Of course, while the costs of a safe climate policy may be manageable at global and national levels, as argued here, such a policy will pose serious challenges for particular economic sectors. But this is entirely logical and acceptable, since higher energy costs will regulate and restructure the economy and affect energy-intensive products, processes, firms, and industries relatively severely. Higher energy prices and costs will thus set into motion a process of creative destruction, which is an inevitable component in the transition to a low-carbon economy. Postponing such a transition will only make it more expensive, while safe levels of atmospheric GHG concentration will get out of reach.

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