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What if solar energy becomes really cheap? A thought experiment on environmental problem shifting

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Solving one environmental problem may often invoke or intensify another one. Such environmental problem shifting (EPS) is a neglected topic in global sustainability research. Indeed, it is difficult to study as it requires the merging of insights from various research areas. Here we identify relevant studies, and provide an illustration and guidelines for the systematic study of EPS. As a modest thought experiment to illustrate the relevance of EPS, we consider solutions to scarcity of energy resources and climate change that, due to their extreme nature, may lead to considerable environmental problem shifting. We qualitatively assess the likely environmental and socioeconomic impacts of three hypothetical energy futures to highlight the possibility that as we resolve one environmental problem, another may be aggravated. We further present a set of guidelines to study EPS in a systematic and focused way. Here we stress that shifting can be mediated by biophysical as well as socioeconomic mechanisms, which means that its analysis requires a genuine interdisciplinary effort.

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Introduction

In considering sustainable futures and associated public policies, we often tend to forget or neglect the complex system of indirect effects that result from major shifts in energy and material resources. For example, reducing the weight of computers may imply the use of more rare or toxic materials. Failure to think in a systemic fashion means we will fail to anticipate unintended consequences with important environmental and socioeconomic effects.

The issue of shifting problems has been under-investigated, perhaps because the study of environmental science and policy is divided into so many disciplines and specializations that each observes only a small part of the complex environmental puzzle. It is true that several environmental scientists have recognized that solving or ameliorating one environmental problem often has unintended consequences; witness terms like *energy rebound*, *carbon leakage*, *displacement or indirect land-use change*, *cascade effects*, *co-benefits (or ancillary benefits) of climate policy*, *quick fixes* and *green paradox* [1–14]. But these studies tend to focus on a single environmental problem rather than on shifting to other problems. In the context of biofuels for climate mitigation, aspects like pollution, water use and associated biodiversity effects have received attention. For example, one study considers the impacts of replacing gasoline with corn ethanol on eutrophication and water scarcity [15•]. Another [16] analyses alternative scenarios to reach Millennium Development Goals (eradication of hunger, universal access to safe drinking water, universal access to modern energy, ensuring clean air, climate change mitigation, and halting biodiversity), taking into account the connections between these. Their Table 3 provides a qualitative view on the interaction between various goals. They find that bio-energy helps achieve the climate goal, but complicates achieving biodiversity and food related goals. Ref [4] (part II, pp. 23–29) includes a brief discussion of qualitative linkages between particular global environmental issues, notably climate, biodiversity, forests, water resources, land use, desertification and stratospheric ozone depletion. In the context of renewable energy development for climate mitigation concerns about various environmental impacts (pollution, noise, wildlife, etc.) of wind, solar and other technologies have received attention [17]. Finally, while the terms 'problem/burden shifting' appear in some writings on life cycle analysis (LCA) (e.g. [18]), this method deals predominantly with trade-offs between criteria rather than with problem shifting. Nevertheless, LCA certainly offers a tool that is helpful in identifying problem shifting, not only between environmental problems but also between stages in the life cycle of a product.

In addition, there are various integrated assessment models, which mostly focus on specific problems, like land use (e.g. IMAGE), climate policy (DICE, RICE, FUND, PAGE, WITCH, MERGE) and acid rain (RAINS). Sometimes these models include some problem shifting effects: for example, GAINS is an extension of the RAINS model to deal with synergies and trade-offs between the control of emissions of local/regional air pollution and global greenhouse gases.[9] Versions of certain climate-change oriented models (PAGE2002 and DICE2007) also include air quality co-benefits of greenhouse gas emissions reduction (for an overview, see [19]). However, as is clear from IAM surveys (e.g. [20–22]), most of the existing integrated assessment models for global climate change do not pay much attention to environmental problem shifting. A notable exception was the ambitious model exercise TARGETS [23], which looked at interactions between energy, population, human health, water, land, food, and global biochemical cycles. Somewhat in the spirit of the systems dynamics WORLD models by [24,25] develops a model offering an integrated perspective on climate, energy, water and biodiversity. Other systems dynamics approaches, which in principle allow best for capturing continuous and nonlinear interactions between different environmental issues, are FREE [26], ANEMI [27] and Threshold-21 [28].

However, most if not all of the previous studies do not cover the full range of relevant environmental impact indicators, such as the nine planetary boundaries proposed by Rockström *et al.* [29].[10] This means that they do not offer a complete perspective on potential shifts in environmental problems due to policies or strategies aimed at reducing greenhouse gas emissions. Moreover, typically models that are good in describing environmental component linkages, including responses of biodiversity and ecosystem functions to climate change (IMAGE, MESSAGE-MACRO, MIT-IGSM and AIM), have a very simple representation of behavioral and economic dimensions, or these are missing altogether. This means that it is difficult to trace problem shifting due to behavioral or economic mechanisms.

The paper provides a thought experiment to illustrate environmental problem shifting (EPS) for solutions to energy-climate problems. A model that is up to the ambitious task of assessing the full extent of environmental problem shifting in this context does not exist, motivating the approach of a thought experiment. This is aimed at presenting scenarios that go in very different directions, to show that environmental problem shifting matters for (political choices about) climate policy futures. One scenario reflects the hope of many people that renewable energy will become very cheap in some (distant) future and we argue that this can have all kinds of unforeseen and unwanted environmental shifting impacts, that is, it is not necessarily a blessing as one might be inclined to think. This is an important insight for the debate on climate policy.

Next the paper presents a set of guidelines for systematically assessing environmental problem shifting. With this we hope to contribute to more serious attention for this issue in local and global environmental research, whether using formal models (integrated assessment) or not.

The remainder of this article is organized as follows. Section ''Scenarios and evaluation criteria'' motivates the focus on cheap versus expensive energy, and associated innovation versus carbon pricing policies, as the basis for the formulation of a set of scenarios. In addition, it proposes the nine planetary boundaries indicators and a set of socioeconomic indicators for the EPS evaluation and comparison of the scenarios. Section ''Confronting scenarios with environmental rebound categories'' assesses the consequences of each scenario. This approach means that our study, though it is a thought experiment only, is intended to be conceptually more comprehensive than earlier work aimed at studying the problem-shifting challenge. Section ''Guidelines for assessing environmental problem shifting'' presents a set of guidelines for addressing systematically and effectively environmental problem shifting. The conclusions conclude.

Scenarios and evaluation criteria

For illustrative purposes, building upon the literature presented, we qualitatively assess environmental problem shifting of perceived solutions to energy-climate problems. We formulate three distinct scenarios to represent energy futures and assess their impact on a range of environmental indicators to check whether solutions proposed to reduce GHG emissions will lead to a shift towards other environmental problems. We also assess

[9] See http://webarchive.iiasa.ac.at/rains/gains-methodology.html?sb=10.

[10] An exception is a recent study by Liu et al. [30•] which was published after the first version of this article was submitted. It adopts a broad perspective on system integration for sustainability and is motivated by the fact that 'Global sustainability challenges, from maintaining biodiversity to providing clean air and water, are closely interconnected yet often separately studied and managed.' Its focus is, however, not environmental problem shifting as is ours, and despite its stated goal it deals more with global indirect or hidden effects in particular environmental dimensions (e.g., virtual water use) than with interactions between environmental problems. Note in this respect a particular issue discussed in Liu et al., namely 'telecoupled processes', such as international trade and information flows, which cause certain environmentally relevant practices (e.g., biofuel programs) to diffuse across the globe (see also [31]).