perceive it as mostly a natural phenomenon and, as such, beyond the control of policymakers[7]. Citizens may be more likely to blame politicians for the real or perceived effects of climate policies than for those of climate change itself. Until the public, and in turn policymakers, value policy actions on climate change as much as it fears the possible consequences of those actions for things that it cares about, such as economic growth, innovations in climate policy will tend to be negative.

What is particularly interesting about this study is that such a conclusion is, in hindsight, blindingly obvious. Policy research has shown for decades that in most areas crying out for effective policy innovations, including those on health, poverty or the environment, such innovations are extremely rare[8]. Instead, new policies tend to be negative — at best they usually involve minor alterations to existing policies rather than robust interventions that change the status quo. Why should policy innovation on climate change be different? Indeed, climate change is even more vulnerable to policy negativity than many other issue areas because it is an extraordinarily complex environmental phenomenon. It requires policies that will affect nearly everyone — often hitting individuals in the pocket through higher prices for energy or by requiring them to stop common behaviours that result in greenhouse gas pollution — however, in most cases results will materialize only in the relatively distant future, beyond the terms of office of those making the policies.

As long as governments continue to claim that extreme weather events and other likely manifestations of climate change are unpredictable, unavoidable or simply natural — as, for example, when Australian Prime Minister Tony Abbot responded to extremely deadly wildfires by arguing that Australia has always had wildfires[9] — policy innovations will be too little, too late at best. At worst they will involve attacking the science of climate change, which has been the case for decades, most profoundly in the USA[10].

The implication of the bias towards negative policy innovation is worrying: only when the consequences of climate change are severe enough to consistently evoke strong public concern will policy innovation be positive. As Howlett puts it, an "increase in the visibility of climate change effects is likely to increase the need for governments to respond on a more consistent and substantive basis,"[2] even if governments are not yet held responsible for creating the problem.

Sadly, by the time climate change impacts are bad enough for policymakers to react effectively, it will probably be too late. Policy innovation in the near future can, at best, mitigate the worst effects of climate change in the distant future. Even positive policy innovation now cannot avoid negative outcomes for future generations. Whatever the future policy scenario, substantial negativity is inevitable. ❐

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References

1. Harris, P. G. *Nat. Resour. J.* **47,** 195–224 (2007).
2. Howlett, M. *Glob. Environ. Change* http://doi.org/rtp (2014).
3. Peters, G. P. *et al. Nature Clim. Change* **3,** 4–6 (2013).
4. IPCC *Climate Change 2013: The Physical Science Basis* (eds Stocker, E. F. *et al.*) (Cambridge Univ. Press, 2013).
5. IPCC *Climate Change 2007: Impacts, Adaptation and Vulnerability* (eds Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J. & Hanson, C. E.) (Cambridge Univ. Press, 2007).
6. IPCC *Climate Change 2007: Mitigation of Climate Change* (eds Metz, B., Davidson, O. R., Bosch, P. R., Dave, R & Meyer, L. A.) (Cambridge Univ. Press, 2007).
7. Conner, L. H. & Higginbotham, N. *Glob. Environ. Change* **23,** 1852–1861 (2013).
8. Howlett, M. & Migone, A. *Policy Soc.* **30,** 53–62 (2011).
9. McGuirk, R. *Huffington Post* (25 October 2013); http://go.nature.com/g6DCMw
10. Dunlap, R. E. & McCright, A. M. in *The Oxford Handbook of Climate Change and Society* (eds Dryzek, J. S., Norgaard, R. B. & Schlosberg, D.) 144–160 (Oxford Univ. Press, 2011).

WATER-ENERGY NEXUS

Assessing integrated systems

The various supply chains that deliver the services society needs are often managed in silos. Research now shows the advantages of integrated management.

Mark Howells and H-Holger Rogner

Living in the beautiful cities of Stockholm and Vienna we note, with some irritation, occasional interruptions to their scenic walkways. Striving to provide services, a street might get torn up several times within a few months. First to do sewage repairs, then to lay new high-capacity data cables and finally to increase the capacity of the gas mains — efforts that might cost three times more tax money than if these activities were coordinated. And this is just an example at local level — globally it can be worse. Our societies are simply not organized to undertake integrated planning and action[1]. We spend far more than we need to deliver the services societies demand. Writing in *Environmental Science and Technology*, Bartos and Chester[2] show the missed opportunities from the lack of integrated water-energy management in the state of Arizona, USA.

The delivery systems of society's services consist of a chain of activity. They originate from natural resources and ecosystems. These are extracted, processed and transported to provide products and services. Those chains are shaped by economics, technology and policies — notably to ensure secure supplies.

Society's 'delivery chains' have traditionally been managed individually. Initially, interactions between many chains were largely inconsequential — their supplies were abundant and our demand was small. For practical reasons, separate management also allows for delineated responsibility and focused planning. Hence, at all governmental levels, we find authorities for energy, water, agriculture and so on, each tasked with their own sectoral mandates. Such mandates often do not include any assessments of the impacts of action in one sector on others. A notable exception is the European Commission's Strategic Environmental Assessments. These assessments are required for certain types of public plans and programmes (for example, on land use, transport, waste and water management, energy and agriculture)[3].

Although practical, delineation generally discourages coordination. At best, it misses synergies; at worst it creates conflict. Sectoral interdependencies are increasing. We require staggering amounts of water to provide food and energy. Water systems require (and can produce) large quantities of energy. At the same time, these sectors affect and are vulnerable to a changing climate.

Moving towards more integrated governance is not trivial. It requires new skills, tools and motivation. It is here that the study by Bartos and Chester[2] makes an addition. Using a recently completed integrated water-energy model, they illustrate how the water and energy systems are intertwined in Arizona. Yet the state policies are not. The researchers show that measures to reduce water use can indirectly reduce energy supply needs. Water lifting, distribution pumping and treatment are electricity intensive. Any programme that lowers water use immediately reduces electricity demand — as well as the fuels required to generate electricity. In fact, Bartos and Chester show that through introducing water-efficiency measures alone, Arizona could reach 16% of its mandated energy-efficiency target. Similarly, by introducing renewable and energy-efficiency measures, indirect water savings can reduce non-agricultural water withdrawals by 1.9–15.0%. When including rough economic estimates, the analysis concludes that the cost reductions, including these indirect savings, are significant. This results in savings not only on state-wide water bills, but also (indirectly) on energy bills — and vice versa. For the socio-economy, this could translate into cheaper services and more efficient resource use. Figure 1 indicates how much energy is embodied in, or used for, irrigation, public supply and electricity generation, as well as how the embedded energy is returned to the environment as waste water or evaporation.

In their approach, Bartos and Chester pay attention to instances where water and energy connect and interact. As the systems and supply chains develop, it compels the analysis of both at the same time. Furthermore, the model points to specific infrastructure and how it might be changed by policy. This allows specific interventions, such as renewable energy portfolio standards or efficiency standards, to be evaluated both in terms of their sectoral and cross-sectoral impacts.

It is a commendable contribution. However — as acknowledged by the authors — more is needed. There are more 'delivery chains' and contexts that need to be concurrently analysed. These might include, among others, agricultural practices and food production, manufacturing processes and transportation systems. Analyses of the interactions with surrounding ecosystems are also needed, as the vital services they provide are, most often, not accounted for — nor economically valued.

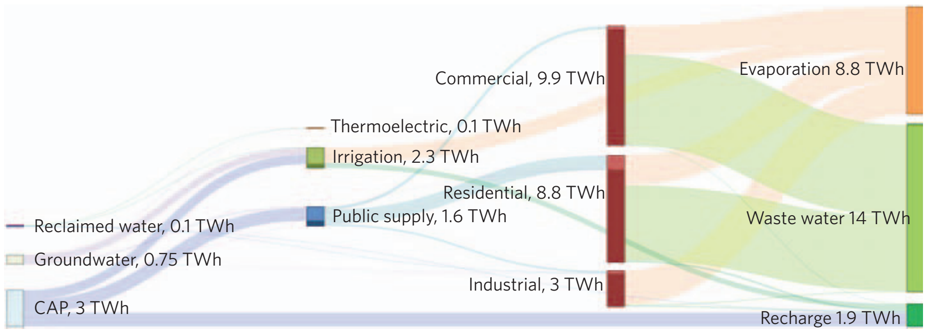

Figure 1 | The embodied energy in the water-cycle components in Arizona, USA in 2008. The breadth of each flow indicates the compounded quantity of energy that is used to manage or treat each water flow. This means that as less water is used, less energy is used. The annual quantity of energy passing through each component is provided in TWh of end-use energy. CAP refers to the Central Arizona Project — a large interbasin transfer project. Columns are disaggregated into two categories: energy added and embedded. The darker portion indicates the energy added at the stage, while the lighter portion indicates embedded energy from previous stages. Figure reproduced with permission from ref. 2, © 2014 ACS.

Moreover, the institutional and financial rules that shape these delivery chains differ, leading to damaging inconsistencies. Water extraction and purchase is predominantly determined by 'allocations'. The structure of which may have little to do with economics. Other resources might be priced and distributed predominantly by the market. Many ecosystem services are not priced, nor subject to allocation rules. These differences lead to distorted resource exploitation and subsequently to expensive services. Yet, the effects are steadily and ominously exacerbated. Together with our growing demands, we simply accelerate the depletion of our diminishing resources.

The potential efficiencies to be gained from increased integration are profound. This is recognized by the United Nations. In response to requests from its member states, its first *Global Sustainable Development Report* includes a special chapter on the climate, land-, energy- and water-development nexus[4]. The analysis was based on a simple 'integrated assessment' model of the delivery chains needed to supply water, food and energy services.

Yet integrated assessments (so called) are not new. At a local level, integrated water resource management or integrated energy planning have existed for some time[5,6]. However, they normally stop after identifying important linkages. Often, they do not model the 'embodied' energy or 'water' in the services modelled. Nor do they model the compound effects of the integrated linked system — where both may complement or, more often, compete with each other.

More formal integrated assessments models — developed with a global scope to investigate global futures — do attempt to make such links. However, owing in part to their scale and their academic heritage, they are not easily translated into national- or state-level policy support.

A new and important feature of the work by Bartos and Chester is precisely its attempted alignment with policymaking. Resources are becoming scarcer and our demands on them are increasing. Change is difficult. Our governance machinery has significant inertia. If policymaking is to take advantage of the opportunities that come with more integration, new intradisciplinary engagement is necessary[7]. ❐

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References

1. Bazilian, M. *et al. Energy Policy* **39,** 7896–7906 (2011).
2. Bartos, M. D. & Chester, M. V. *Environ. Sci. Technol.* **48,** 2139–2149 (2014).
3. *Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the Assessment of the Effects of Certain Plans and Programmes on the Environment* (Eur-Lex, 2001); http://go.nature.com/pmYRty
4. *Global Sustainable Development Report — Executive Summary: Building the Common Future We Want* (United Nations Department of Economic and Social Affairs, Division for Sustainable Development, 2013); http://go.nature.com/GCT4fM
5. Bhattacharyya, S. C. *Energy Economics: Concepts, Issues, Markets and Governance* (Springer, 2011).
6. Rahaman, M. M. & Varis, O. *Sustain. Sci. Pract. Policy* **1,** 15–21 (2005).
7. *Back to Our Common Future: Sustainable Development in the 21st Century (SD21) Project* 21–23 (United Nations Division of Economic and Social Affairs, 2012); http://go.nature.com/8n4E3a