COMMENTARY

Policies to enhance economic feasibility of a sustainable energy transition

Jeroen C. J. M. van den Bergh[1]

Institute of Environmental Science and Technology, Universitat Autònoma de Barcelona, 08193 Bellaterra, Spain; ICREA, 08010 Barcelona, Spain; and Faculty of Economics and Business Administration and Institute for Environmental Studies, VU University, 1081 HV, Amsterdam, The Netherlands

An important task of contemporary academic research is the design of policy that promotes a sustainable energy transition. Dangerman and Schnellnhuber (1) (D&S hereafter) explain theoretically, and show empirically, that it is very difficult to move away from unsustainable technologies. The role of investment funds that go disproportionally to dominant, pollutive technologies is emphasized. The policy suggestion of D&S is modifying corporate law to make shareholders legally liable for environmental impacts of firms in which they invest. The resulting "legal negative feedback loop" to shareholders' decisions will alter the allocation of capital investment in favor of cleaner "niche" technologies. According to D&S, this would "balance the shareholders' zest for unrestricted expansion." They add that it can have a precautionary effect by discouraging investment away from pollutive industries in an early development phase.

Studies on environmental policy tend to focus on changing the behavior of consumers and producers and give considerably less attention to investors. The D&S proposal is therefore a welcome addition to the literature. Investors receive more notice in research on "environmental innovation" and "sustainability transitions" (2, 3). A central policy finding here is that a combination of environmental regulation and innovation support is needed to foster a sustainable energy transition (4). The first will change the costs and benefits of production and thus the profits in the positive feedback cycle of both the dominant and alternative technologies in figures 2–4 of D&S (1), which will reallocate scarce funds in favor of the cleaner technology. The second will stimulate the emergence of new technologies or keep alive expensive technologies that may generate social benefits in the future. Introducing environmental liability of shareholders seems to contribute to both and can thus reinforce the intended effects of existing policies.

D&S use the catchphrase "success of the successful" to denote the well-known positive feedback mechanism driven by increasing returns to scale that can cause lock-in of dirty technologies (5), which obstructs or delays a transition. However, the transition puzzle and barriers to be tackled are really more complex, as is illustrated by the framework in Table 1. The challenges outlined there require adequate instrumental responses, giving rise to a transition policy package. Let us see how the D&S proposal performs in this broader framework.

D&S recognize part of the triple externality problem (a1–a3 in the table), emphasizing lock-in (a3), but do not examine how their instrument would affect innovation (a2). Depending on the precise design of the liability law, risk aversion of investors might lead to inadequate investments in renewable energy technologies because most of these also generate certain negative environmental impacts. Moreover, it is unclear how subtle the D&S instrument is in regulating environmental externalities (a1), because these differ between technologies. Pricing externalities is a quite precise way to do this and should serve as a benchmark.

D&S do not address indirect effects or "escape routes" (b) in a transition process (6). This means their analysis is somewhat incomplete. Here carbon leakage is of particular concern: global warming requires a global solution to avoid leakage through relocation of firms to countries with lax policies. Thus, policy effectiveness would require that countries coordinate any change in corporate legislation to arrange environmental liability of shareholders.

With regard to (c1), a transition to renewable energy is environmentally rational but lacks a strong economic rationale. D&S recognize this by stressing lock-in of the dirty technology. Another fundamental reason is that renewable energy generally has a much lower energy return on energy investment (EROEI) than fossil fuels (7). Conversely, historical transitions from food to firewood, animal power, hydropower, windmill, coal, oil, and electricity meant a change to a more concentrated and thus attractive energy source. Although several of these transitions were bad news for the environment, they were good news for the economy. The reverse is true for the next energy transition. Concerning (c2), technological history teaches us that rapid diffusion of new technologies generally occurs because they introduce new qualities, functions, or services. Instead, environmental innovations are usually factor-saving. Electric cars and renewable electricity save on—or substitute for—the factor fossil fuel. Autonomous market diffusion of technologies like computers or mobile phones therefore does not represent a good analogy for a sustainable energy transition.

With respect to (d), D&S make the useful observation that "Because the technologies of the alternative energy system are still in their late-reorganization and early-exploitation [phases] . . . the alternative energy system is very prone and vulnerable to external perturbations." It is important to understand the transition opportunities and barriers created by the crisis, including funding conditions for renewable energy (8).

D&S talk about the Ω-phase in the panarchy framework (i.e., the positive feedback cycle leading to economic growth at the macrolevel, in turn contributing to energy rebound) (b2). The dominant goal of economic growth in politics forms a barrier to a sustainability transition. The reason is that the discussed lack of economic logic of sustainable energy (c) translates into lower economic productivity and less growth. If we supply all our energy from renewables, a larger share of the labor population will be used in the energy sector, reducing overall productivity of the economy. Moreover, whereas pollutive, technology-rich sectors tend to contribute much to growth, greener service sectors will often use less technology and therefore less energy but as a result be less able to contribute to economic growth.

Low growth is difficult to accept for most unprepared minds. The common optimistic view is to aim for "green growth" (win–win), denying the possibility that this might be unrealistic by assuming we can perfectly decouple (national) income from environmental pressure. There is, however, no evidence for

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[1]E-mail: jeroen.bergh@uab.es.

Table 1. Policy challenges for a transition to sustainable energy

Challenges		Effective policies and strategies
(a) Triple externality problem	(a1) Negative, environmental externality, which means that prices do not reflect social (private + external) costs, thus providing incorrect incentives for consumption, production, investment, and innovation.	Private decisions (by firms, households, investors, and innovators) need to account for external costs throughout the life cycle of products and services (e.g., carbon pricing) Environmentally harmful subsidies need to be removed.
	(a2) Innovation/knowledge externality (positive) causing the investor in innovation activity to not always be able to reap a fair share of the innovation benefits. An uncertain and long-term return on investment in innovation is characteristic of many environmentally relevant innovations.	Protect innovators so they can reap the benefits of their investments (e.g., patent law). Subsidize promising but still expensive technologies. Basic research with low return on investment by the state (universities and state research institutes).
	(a3) Lock-in, which means a positive externality for the dominant technology and a negative externality for new, niche technologies.	Discourage innovation in the dirty technology, subsidize set-up costs and infrastructure of cleaner alternatives, restrict advertising of dirty locked-in product, and use status seeking to sell cleaner alternative (e.g., electric car).
(b) Escape routes: indirect, undesirable, and avoidable effects of well-intended policies and strategies	(b1) Carbon leakage due to relocation of polluters to countries with lax environmental regulation and associated changes in trade patterns.	International climate agreement.
	(b2) Energy or CO_2 rebound: indirect effects of energy conservation that create new energy use.	A hard ceiling to total CO_2 emissions. Carbon pricing. Combination means tradable permits are an effective policy.
	(b3) Environmental rebound: shifting of environmental problems.	Systems analysis of sustainability policies and renewable energy strategies to identify unwanted indirect effects.
	(b4) Green paradox: oil market response to climate/innovation policies.	Externality pricing of fossil fuels (supply policy).
(c) Lack of economic rationale of a sustainable energy transition	(c1) Transition to lower EROEI technologies is environmentally motivated but lacks economic logic. Therefore, it cannot be compared with historical energy transitions.	Improve EROEI of technologies by research and development incentives and public investments. Subsidize niche technology. Feed-in-tariffs for renewable electricity.
	(c2) Environmental innovations are generally factor-saving, not output-quality improving. This means that although innovative technology is more expensive it does not provide relevant new features for users. Diffusion is hampered then.	Try to combine function/quality and factor-saving innovations. Make consumers and producers more conscious about environmental impacts (voluntary action, altruism). Subsidize niche technology.
(d) The financial-economic crisis creates new barriers to energy transition.	(d1) Reduced pubic support of, and investment funds for, renewable energy and energy conservation.	Integrate macroeconomic policies with environmental and innovation policies. Show that energy transition can go along with economic recovery. Prepare society and politics for a lower rate of economic growth.

such decoupling with regard to fossil energy use in the last decades, as documented by D&W. Precaution implies being prepared for the possibility that a sustainability transition leads to—at least temporarily—a low-growth economy (9). Environmental liability of shareholders might assist in cultivating this preparedness.

An important question is whether the D&S instrument can deal well with long-term climate change. Who can be held responsible for climate change impacts of investments done 30 or 50 y ago? Many shareholders may already have passed away. It is not immediately clear that the delayed impact of industries on climate change can be captured by a legal liability approach, let alone how it could address high-impact, low-probability events (10).

To be effective, the D&S policy suggestion requires that potential shareholders well understand the environmental impacts of all technologies, products, and industries. The literature on green venture capital (11) is instructive here because it provides empirical insight about investor preferences, knowledge, and strategies. Environmental liability of shareholders could be designed to be dynamic, involving a learning phase and adapting liability over time when knowledge about environmental impacts of technologies is more complete and publicly accessible. This, however, means a considerable transaction cost as corporate law needs continuous adaptation.

A final question concerns the radical implications of the D&S instrument. Once implemented, few investors would dare to still invest in dirty industries. Because these make up perhaps 90% or more of the economy, a drastic change in investment would create a serious risk of economic instability. To avoid this, one could design the liability law so as to moderate the redirection of investments or allow for a transitional period. It may be true—in the words of D&S—that "…systems innovations tend to be children of crises," but we should try to prevent the reverse causality.

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