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OPINION

Powering the next wave of green energy innovation

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How solar and wind became cheap is a formidable success story. Whether this success can be emulated in other areas of green energy innovation critical for achieving net-zero emission targets is a different question. During the last two decades, massive innovations changed how energy is generated and used. But many technical challenges remain to scale-up renewables, electrify transportation and decarbonize heavy industry. Achieving this will place unprecedented pressure on the electrical grid to deliver prodigious amounts of clean energy. To cope with these pressures, further R&D efforts must emphasize technologies to complement renewable energy.

In the first decade of the 21st century, innovation played a key role lowering the costs of wind and solar energy. For example, wind turbine rotors more than doubled in size, increasing cost-effectiveness, and new wafer-cutting techniques helped reduce raw materials used in manufacturing solar panels [1]. Patenting in these technologies increased by a factor of three or more from 2006 to 2011 (Fig 1). While patents have fallen since, the dramatic decrease in low-carbon energy prices suggests the wave of innovation in the early 2000s succeeded. More concerning, we observe both similar declines and lower innovation levels in technologies that have not yet attained maturity and are critical for achieving decarbonization goals, such as smart grids and hydrogen and fuel cells. Continued innovation in these enabling technologies that complement readily available clean technologies such as intermittent renewables is vital to stay on track to limiting global warming to no more than 1.5˚ Celsius [2]. What lessons have we learned from the success of wind and solar, and how can they be applied to enabling green energy technologies?

A policy mix to support diverse technology needs

While the costs of wind and solar were falling over the past decade, their primary competition came from fossil fuels. The goals of low-carbon energy policy at that time were clear—to lower costs and bring low-carbon energy to the market as soon as possible. Today, low-carbon energy policy operates in a more complicated landscape. In many cases, renewables already cost less that fossil fuels. But because of both technological and supply constraints, renewable sources can not yet satisfy all our energy needs. Energy policy now operates in a world where policy both promotes expanded use of renewables ready for the market while still needing to provide incentives to develop technologies further from the market and necessary for full decarbonization. In this policy environment, no one low-carbon energy technology policy is a silver bullet. Identifying the policies needed at different stages of technological development is key.

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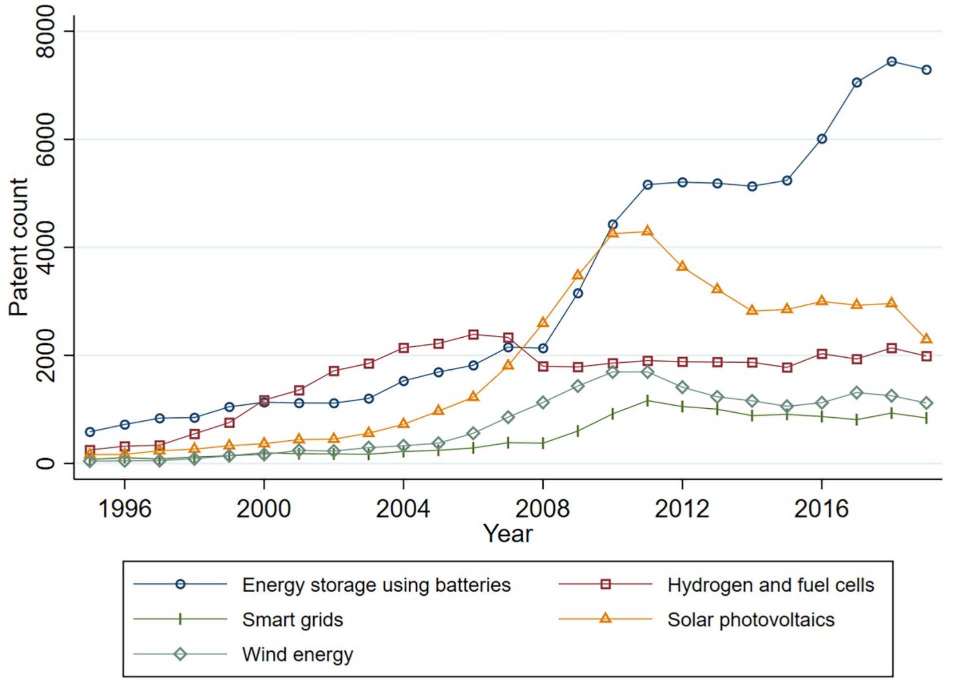

Fig 1. Trends in clean energy patents. Notes: Figure shows global counts of energy patents for patents filed in two or more countries. Patents are sorted by priority year. Patent extractions from the EPO World Patent Statistical Database (PATSTAT).

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In all cases, demand matters. Demand for low-carbon energy technologies depends on effective environmental policy. For mature technologies close to market-ready, technology-neutral policies providing broad mandates, such as reducing emissions to a certain level, are best. These policies provide policy goals, but leave it to consumers and firms to decide how to best comply. Examples include a carbon tax or cap-and-trade, which targets all emissions equally. But when actors are left to their own devices, they pick the lowest cost technologies. Simply relying on technologies already market-ready cannot deliver a zero-carbon economy. Developing complementary technologies requires a portfolio of policies that target current and future technological needs.

What can we learn from the success of solar?

Recent improvements in solar photovoltaics (PV) demonstrate the role of technology-specific policies for encouraging the deployment of technologies that are not yet cost-competitive. In the early 2000s, onshore wind was close to competitive with fossil fuels, but solar PV was not. As a result, innovation in solar PV occurred in countries with technology-specific policies. Most notably, German feed-in tariffs were over five times higher for solar than for wind [3], increasing demand and encouraging innovation that reduced PV costs [4]. Moving forward, while technology-specific policies raise short-term costs, using them judiciously can help promote the development of low-emission technologies further from the market, such as offshore wind or carbon capture and sequestration, to achieve long-term goals.

For many early-stage technologies, targeted public R&D support is an important first step to help lower costs. Large US government R&D investments in solar energy in the 1970s provided the scientific foundation for the global advancements that followed [5]. Public R&D can also target emerging breakthroughs in seemingly established technologies. While broad-based demand policies promote the use of first-generation technologies, government R&D can support second generation advancements [6]. Battery technologies are an example. Although patenting activity is high (Fig 1), because the market for electric vehicle batteries is ten times larger than the market for grid scale batteries, battery innovation has focused on reducing size and weight, which is important in non-stationary applications. There have been fewer advances in technologies that are better suited to the needs of stationary storage [7]. Examples include flow batteries and lithium iron phosphate batteries, which are in earlier stages than lithium-ion batteries. Public R&D investments can step in to fill such gaps left by the private sector.

The next wave of green energy technology is different

Technology-specific policies to support R&D will not be enough. Enabling technologies imply new investments in infrastructure. Early investments in this infrastructure can provide large spillover benefits [8]. Better management of the grid benefits all users, including producers of wind and solar. With appropriate adaptations to pipelines, both "green" and "blue" hydrogen produced from fossil fuels with carbon capture and storage could become an energy source for hard to decarbonize sectors such as iron and steel [9].

However, technologies such as hydrogen remain expensive and may never achieve cost parity with other energy sources. Similarly, without emissions regulation, carbon capture and storage increases a firm's production costs without providing financial benefits to the firm, making voluntary adoption of carbon capture and storage unlikely. Early investments earmarked in the United States' Inflation Reduction Act provide a down payment on future climate policy by making initial investments in needed infrastructure. But without a price on carbon or other direct regulation, more expensive technologies are unlikely to achieve the scale needed to meet zero carbon goals.

References

1. International Renewable Energy Agency. Renewable Technology Innovation Indicators: Mapping progress in costs, patents and standards. Abu Dhabi: International Renewable Energy Agency; 2022. Available from: https://www.irena.org/publications/2022/Mar/Renewable-Technology-Innovation-Indicators.
2. International Energy Agency. Patents and the energy transition, Paris, France: IEA; 2021. Available from: https://www.iea.org/reports/patents-and-the-energy-transition.
3. Johnstone N, Haščič I, Popp D. Renewable Energy Policies and Technological Innovation: Evidence Based on Patent Counts. Environ Resour Econ. 2010; 45(1): 133–155. https://doi.org/10.1007/s10640-009-9309-1
4. Gerarden T. Demanding Innovation: The Impact of Consumer Subsidies on Solar Panel Production Costs. Manage Sci. Forthcoming. Available from: https://toddgerarden.com/research.
5. Nemet GF. How Solar Energy Became Cheap: A Model for Low-Carbon Innovation. New York: Routledge Press; 2019.
6. Costantini V, Crespi F, Curci Y. A Keyword Selection Method for Mapping Technological Knowledge in Specific Sectors Through Patent Data: the Case of Biofuels Sector. Economics of Innovation and New Technology. 2015; 24(4): 282–308. https://doi.org/10.1080/10438599.2014.942583
7. International Energy Agency. Energy Storage. 2021 [cited 2022 Jul 19]. Available from: https://www.iea.org/reports/energy-storage.
8. Popp D, Vona F, Grégoire-Zawilski M, Marin G. The Next Wave of Energy Innovation: Which Technologies? Which Skills? NBER working paper series; working paper 30343 [Preprint]. 2022 [cited 2022 Nov 11]. Available from: https://www.nber.org/papers/w30343.
9. International Energy Agency. The Future of Hydrogen. Paris, France: IEA; 2019. Available from: https://www.iea.org/reports/the-future-of-hydrogen.