1970s, such as Ron Silliman, Lyn Hejinian, and Bernadette Mayer).

Incomprehensible? Yes, often. But it misses the mark to say that the simple has been made so. Poetry is a kind of laboratory environment where language can be brought to exhibit all sorts of odd behaviors that won't occur in plain prose. The process may appear bizarre, and the results ambiguous. Surely a physicist can relate.

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Charles Day's column, "Physics and poetry," in the April 2022 issue (page 8) is correct to push back on claims that the two are "incompatible" (attributed to Paul Dirac). But I disagree with one of his later statements, "Physics is abstraction. Its use for metaphor and simile is limited."

Physics is rich with metaphors, its very abstraction itself perhaps accounting for many of them. The pendulum as an oscillation about a mean between two limits on either side of an equilibrium is a hoary metaphor in ordinary language and the social sciences. It gets an even wider meaning in the hands of a physicist who sees the same mathematics and physics of harmonic oscillations in contexts far from material bobs on strings or swaying branches. Richard Feynman, a name that Day rightly invokes, rendered poetically many a physical theme and saw in the design of a Japanese gate a poetic "explanation" for broken symmetry in nature as seen in theoretical physics.[1] Some other examples of metaphors across physics are in my book, *The Beauty of Physics: Patterns, Principles, and Perspectives* (2014).

Reference

1. R. P. Feynman, *Six Not-So-Easy Pieces: Einstein's Relativity, Symmetry, and Space-Time*, Basic Books (2011), p. 47.

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The clean-energy challenge

The Issues and Events item "Electrification of cars and trucks likely won't disrupt the grid" (Physics Today, April 2022, page 22) by David Kramer is timely and accurate as far as it goes. But by omitting mention of nonhighway transportation, and the rest of the economy for that matter, it unintentionally makes the growth in electricity usage on the path to decarbonization of our economy seem to be nearly business as usual. Several recent studies, however, show that a carbon-neutral US economy in 2050 will require around four times as much electricity as we use today.[1–3]

Synthesis of chemical fuel for aviation, military, and nonhighway vehicles will require more electricity than the electrification of highway vehicles discussed in Kramer's story. The electrification of homes, businesses, and industry—including synthesis of hydrocarbon feedstocks—will require twice as much again. That prodigious increase in generation, transmission, and, hopefully, storage is most certainly different from what was needed to support the introduction of air conditioning.

The new electric grid will be much larger and will operate very differently from the old one. Power will be transmitted longer distances from regions where sunlight and wind are abundant. Roughly half that power will be for battery charging and a massive new electrochemical industry, both amenable to load management to match the remaining intermittence of renewable power supply. The tendency to treat decarbonization of economic sectors in isolation and thereby miss the big picture is in part a reflection of the incremental approach in our policy. To plan and finance the greatest industrial build-out since the railroad boom of the late 19th century, we must have a comprehensive policy that sets clear goals and brings long-term investor confidence. And we need it soon. We only have 30 years to complete the project!

References

1. E. Larson et al., *Net-Zero America: Potential Pathways, Infrastructure, and Impacts*, Princeton U. (29 October 2021).
2. M. Ram et al., *Global Energy System Based on 100% Renewable Energy: Power, Heat, Transport and Desalination Sectors*, Lappeenranta U. Technology and Energy Watch Group (March 2019).
3. J. H. Williams et al., *AGU Adv.* **2**, e2020AV000284 (2021).

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David Kramer has in the past two years written several items discussing components of the clean-energy challenge. One from the April 2022 issue is on charging electric vehicles, or EVs (page 22), and another from the September 2021 issue is on energy storage (page 20).

While the stories are informative, both are missing context. For example, the story on EVs doesn't discuss how they are only as clean and efficient as the process by which the required electricity is produced. The storage story fails to acknowledge that grid-scale storage capacity adequate to power cities or countries is not and will not be available in the foreseeable future. Even more importantly, dependence on storage is not acceptable, even if attainable, because no one knows the duration of future wind and solar droughts.

I urge Physics Today to do more to rationalize the discussion of renewable energy.

That renewable energy is intermittent is not contentious. That renewable energy sources must be complemented by storage or backup is not contentious. That grid-scale storage is unavailable at urban scale may be more contentious but is nonetheless true. Relying on backup implies that whenever renewables are producing power, their backup (which is paid for) sits idle. Thus, renewables don't increase capacity; they duplicate dispatchable (always available) sources. That duplication is responsible


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for California's "duck curve," discussed by Kramer.

As California and Germany have demonstrated, renewables can't replace grid-scale dispatchables, of which there are just two, hydrocarbons and nuclear. It appears that fusion will enter the market in the same time frame as molten-salt fission reactors, but it is unlikely to be cost competitive. Fission has an attractive safety record, and molten-salt reactors are both safer still and cheaper than existing reactors. A plausible future is fusion for the rich and fission for the rest. An especially good discussion of the inadequacy of both energy storage and renewables generally is available at https://jackdevanney.substack.com/p/nuclear-and-windsolar.

There are only four fundamental forces in nature, and their strengths differ dramatically. Those differences are manifest in the energy density and footprint of competing energy technologies. For example, the relative strength of nuclear forces allows hydrocarbon furnaces to be "surgically" replaced by nuclear reactors, leaving turbines and other infrastructure in place. Conversely, the extreme weakness of gravity makes storage based on raising and dropping weights unpromising.

Grid-scale renewable energy is a distraction, one that is delaying productive action on an important problem. Physics Today can play an important role here.

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Correction

April 2022, page 8—Cornell University is incorrectly described as Richard Feynman's alma mater. He was a professor, but never a student, at Cornell. PT