

ELECTRIFY: AN OPTIMIST'S PLAYBOOK FOR OUR CLEAN ENERGY FUTURE

By Saul Griffith
Reviewed by Kenneth A. Barry[*]

An impassioned plea to retire and replace all existing equipment in the fossil fuel chain – from exploration and production to utilization – Saul Griffith's *Electrify: An Optimist's Playbook for our Clean Energy Future* (2021) (*Electrify*) is quite the opposite of Steven E. Koonin's *Unsettled* (2021). The two scientist-authors represent bookends in the debate over whether society must rapidly ramp down its dependence on hydrocarbons to meet its energy needs and mitigate the presence of greenhouse gases (GHG) in the atmosphere.

Griffith[1]– unlike Koonin – does not hesitate to prescribe concrete solutions; his book is full of them. Indeed, the author characterizes *Electrify* as an "action plan to fight for the future," as well as a technical roadmap to a clean-energy future.[2] In his opening salvo ("Preface," pp. xi – xiii), he invokes the language of war preparation to underscore both the scale and urgency of his recommendations:

"America needs nothing short of a concerted mobilization of technology, industry, labor, regulatory reform, and, critically, finance."[3]

To pull off the transformation, Griffith declares: "We need to triple the amount of electricity delivered in the United States[4] What is required is a moonshot engineering project to deliver a new energy grid with new rules – a grid that operates more like the internet."[5] However, consistent with his subtitle – "an optimist's playbook" – Griffith contends that if his remedies are adopted, energy will be cheaper and more plentiful in the long run, advising "The consequence of getting the technology, financing, and regulations right is that every family in the United States can save thousands of dollars each year."[6] He also envisions an avalanche of employment to help the country rebound from the "pandemic and economic crisis," citing a colleague's opinion that "as many as 25 million good-

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1. The book jacket describes Griffith as an "inventor, entrepreneur, and engineer," founder of Rewiring America (a nonprofit organization whose mission is to "decarbonize America by electrifying everything). In the text, he labels himself an "expert in energy systems." STEVEN KOONIN, ELECTRIFY: AN OPTIMIST'S PLAYBOOK FOR OUR CLEAN ENERGY FUTURE 2 (2021) ("*Electrify*").

2. *Id.* at xi, 2.

3. *Id.* at xi.

4. Griffith's book is aimed squarely at policies and practices in the United States, though he occasionally broadens his perspective.

5. *Electrify*, *supra* note 1, at xiii.

6. *Id.*

paying jobs" will flow from the conversion of all U.S. energy systems to "clean energy" solutions.[7]

Occasionally, Griffith's enthusiasm can bubble over into odd statements. For example, he muses in his Preface that "[with] our future in jeopardy. . . . Billionaires may dream of escaping to Mars, but the rest of us . . . we have to stay and fight." Readers may reflect that Mars's atmosphere is less hospitable than Earth's may be under even the worst-case scenarios painted by climate scientists.

Consistent with his call for radical and sweeping action, Griffith pounds the table for a halt to building or procuring "machines or technologies" that utilize fossil fuels. "There isn't time," he pleads, "for everyone to install one more natural gas furnace in their basement; there is no place for a new natural gas 'peaker' plant . . . .Whatever fossil fuel machinery you own, whether it is as a grid operator, a small business, or a home, that fossil machinery needs to be your last."[8]

I. THE "SCIENCE IS IN"; THE DANGERS ARE LOOMING

Griffith insists that "we can no longer debate the science," even if "for some people, science-based arguments will never be enough."[9] He evinces complete faith in climate models and their oftentimes frightening predictions:

"Scientists have written a large body of work on global warming and can predict the future climate from estimates of our current carbon emissions. We know, with certainty, that we are hurtling toward multiple environmental and human catastrophes."[10]

As a foretaste of impending disaster, Griffith provides a litany of specific, weather-related calamities the planet's inhabitants have endured in recent years – or will face more frequently in the future, he believes – *if* global average temperatures are allowed to increase beyond the red lines drawn by the U.N.'s Intergovernmental Panel on Climate Change (IPCC) (*i.e.,* 1.5 C. or, at worst, 2 C. above preindustrial levels).[11] Such calamities are directly traceable, in Griffith's view, to the build-up of excessive GHG emissions. The stark choice according to *Electrify* is this: either nations can continue down the perilous path they're now on, or – through bold, visionary action – not only avert a proliferation of environmental crises but also kick a virtuous economic cycle into gear:

This is a chance to revitalize our cities, rejuvenate our suburbs, and reignite our small towns. We can rebuild a prosperous and inclusive middle class, as we enjoyed after World War II, with tens of millions of good new jobs . . . . If America does it right, everyone's energy costs will go down. Everyone has a role to play in the war effort.[12]

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7. *Id.* As an indication of how quickly things change in the economy, however, as of early 2022 (the date of this review), unemployment is back to the low single digits in the United States, and the biggest challenge is to find applicants to fill the numerous open jobs.

8. *Id.* at 2.

9. *Electrify*, *supra* note 1, at 11.

10. *Id.* The book at this point refers readers to a "primer on climate science" in appendix C.

11. *Id* at 12, 14.

12. *Id.* at 20. In the chapter that immediate follows ("Emergencies Are Opportunities for Lasting Change," pp. 21-28), Griffith offers a montage of moments in United States history where leadership has re-

Thus, at the heart of the book is an unabashedly populist message – often repeated – that making the necessary changes to ward off a climate crisis won't be a bitter pill, but rather a pathway to a healthier – and financially more solvent – society.

II. EFFICIENCIES APLENTY

Another pillar of Griffith's optimistic outlook is his anticipation of substantial efficiency gains attainable in a greener energy economy. However, this is not anything like the conservation-first, "make-do-with-less" efficiency preached from the 1970s on, when oil became a scarcer and dearer commodity in the aftermath of OPEC's market manipulations. Rather, Griffith prophesizes a "new narrative":

> . . . a "story about what we stand to win – a cleaner electrified future with comfortable homes and zippy cars – which is better than nightmares about what we have to lose. We have a path to decarbonization that will require changes, to be sure, but not deprivation."[13]

Griffith's rejection of efficiency as sacrifice is followed by extended examination of the ways fuels are currently produced and consumed – broken down by individual sectors of the economy (*e.g.*, industrial, commercial, and residential) and by application (*e.g.*, space heating or cooling, transportation, or manufacturing processes).[14] It turns out the author spent a good part of his career studying fuel characteristics and sector-based energy usage, and has a lot to say on the topic. A distinctive argument in *Electrify* is that developing a greener fuel mix should *not* focus on producing decarbonized liquid or gaseous fuels – that is, the kinds of fuels that could more easily replace fossil fuels in the existing infrastructure. Griffith predicates this advice on efficiency – specifically, his belief that the steps involved in producing, transporting, and converting such fuels to useful energy entail excessive losses at each phase. In sum, the author submits that "machines" that run on the combustion of liquid or gaseous fuels – whether petroleum-based or one of the greener alternatives – waste too much energy versus an across-the-board conversion to infrastructure running on electricity (preferably sourced from the wind or the sun).

Griffith employs charts (sometimes rather busy ones) to illustrate the energy flows and losses occurring in the value chain from extraction and refining to transportation and utilization. Notwithstanding the complex detail of this presentation, Griffith has an overarching point to drive home: that through much greater electrification coupled with decarbonized power generation, "we probably only need 42% of the primary energy we need today . . . ."[15] After offering that arresting data point, he retreats from being so "granular," acknowledging that a

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sponded to challenges or crises with major programs, often entailing heavy financial lifts. The New Deal, the mobilization for WW II, and the Space Race are a few examples of this tour of inflection points in 20th C. history.

13. *Electrify*, *supra* note 1, at 47.

14. See generally *id.* at 51–61 ("Electrify!" chapter).

15. *Id.* at 61.

country's aggregate energy demands fluctuate with advancements in technology, new inventions, and new pastimes:[16]

Taking these variables into account, it is simplest to say that Americans will only need half the energy they use today, if we electrify everything while improving our lives. What a win.[17]

In this unmistakably upbeat manner, *Electrify* reassures us that we won't have to downsize or turn down the thermostats in our homes; that our cars can be "sportier when they are electric"; that air quality will improve; that we won't have to switch to mass transport or "wear a Jimmy Carter sweater"; and that we won't even have to "ban flying."[18]

Growing the Grid

To achieve the wholesale benefits Griffith envisions that by electrifying the energy economy, he acknowledges that we'll need a lot more of the stuff – in fact, three times the current amount of power production.[19] So he devotes a chapter – "Where Will We Get All That Electricity?" – to pondering this sizeable question.

Since the energy of the future must be all decarbonized in Griffith's worldview, he looks for supply to the major renewables – wind, solar, hydroelectric – and "possibly" also some nuclear (penciling in the latter because not all regions have ample solar, wind, or hydro resources).[20] In areas near the ocean, he expects "offshore wind likely to be the big producer."[21] In a digression on whether nuclear energy arguably fits into the big picture, Griffith alludes to a fierce controversy among university professors over whether "solar, wind, and water" can, on their own, provide the required capacity and reliability. When a Stanford professor, Mark Jacobson, contended that these renewable resources were indeed equal to the task, it produced "pushback to this proposal that was vicious . . . even by academia's petty standards . . . ."[22] The author implies that Jacobson may be "too anti-nuclear," but then hints that achieving reliability from renewables alone may be "easier than we think," ultimately deferring to a later chapter for more on the question.[23]

Returning to his vision of the future's generation mix, Griffith observes that the "heavy lifting" will be done by solar and wind; that the "majority" of renewable energy will come from these two resources *plus* geothermal and hydro (supplemented by "moderate nuclear and some biofuels as a backstop"), and – finally – that the "exact balance" will be shaped by regional considerations, market forces, and public opinion.[24]

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16. *Id.*

17. *Id.*

18. *Electrify*, *supra* note 1, at 61. For the airplane application, Griffith clarifies that biofuels, rather than batteries, will be a sustainable replacement.

19. *Id.* at 63.

20. *Id.* at 65.

21. *Id.*

22. *Electrify*, *supra* note 1, at 65.

23. *Id.*

24. *Id.* at 66.

In any event, *Electrify* foresees "solar panels and windmills" becoming ubiquitous. An all-solar grid, Griffith notes, would require occupying about 1% of the land mass – an amount equivalent to the space taken up by roads.[25] Rooftops, parking lots, and commercial and industrial buildings would do "double duty" as solar panel collectors, while lands currently used to farm crops would also host wind farms. In round numbers, Griffith estimates that the United States would need to generate 1500-1800 gigawatts (GW) to serve his all-electric society, which would require 15 million acres of panels in an all-solar scenario, or 100 million acres of wind farms (in an all-wind-energy construct).[26] If these numbers seem overwhelming, Griffith reminds us that the playing field – the entire U.S. land mass – contains 2.4 billion acres.[27]

Delving further into exactly where all these solar panels might go, for starters Griffith sets up – and knocks down – two straw men. His first extreme hypothesis is a central station in the Arizona desert that would power "all of America"; the other, which he says is favored by some environmentalists, is an all-distributed model (*i.e.,* limited to the rooftops of occupied buildings). But the former doesn't work, Griffith maintains, because the transmission and distribution would be prohibitively costly; and the other – a fully distributed model – would be untenable because there simply isn't enough residential or small business roof space to go around; industrial and commercial installations, *inter alia,* will also be needed. His conclusion, unsurprisingly, is that system expansion will require an all-of-the-above approach: some centralized installations (presumably *not* in remote deserts), along with exploiting "all the distributed energy we can harness."[28] Highway medians and parking lots are also fair game, in Griffith's spectrum of possibilities.[29]

Similarly, Griffith takes stock of lands that can play host to wind farms – emphasizing active and idle cropland, along with pasturage tracts – and finds these more than sufficient.[30] As to the possibility that "not in my backyard" attitudes could resist the prospect of windmills dotting the landscape, he offers this series of retorts: (1) fossil fuels "are pervasive and pollute everyone's back yard"; (2) society has "learned to live with a lot of changes" to the landscape; (3) we'll have in return "cheaper energy" and cleaner air; and (4) "we will have to balance land use with energy needs."[31] Whether these arguments will resonate in rural America – especially in hydrocarbon-producing states – or persuade conservationists who may prefer not to see windmill panoramas wherever they turn

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25. *Id.*

26. *Electrify*, *supra* note 1, at 66.

27. *Id.* To help us visualize the relative land space required, Griffith includes a page with various-sized squares indicating how much land, proportionately, is devoted to croplands, forests, pasture, rural parks, cities, roadways, *etc. Id.* at 67.

28. *Id.* at 68. It may be that some homeowners don't want to see solar panels adorning their own roofs or those of their neighbors; but aesthetic consideration isn't addressed. Further, inasmuch as distribution systems are already installed where people live, it is not clear that a relatively more centralized approach to siting solar collectors would cost too much on the transmission and distribution side.

29. *Id.*

30. *Electrify*, *supra* note 1, at 69.

31. *Id.* at 69–70.

– remains to be seen. On the other hand, some farmers and ranchers may be eager for any incremental income from wind power installations. It could make for quite a policy tussle down the road.

In a longer discussion on the long-term viability of nuclear energy – a mature, low-carbon technology now in place – Griffith observes that the total cost has proven far greater than once anticipated ("likely more expensive than renewables") even though he concedes operating costs are low and output is reliable.[32] He also takes on the traditional paradigm of system planners who hold that some "baseload" energy is essential, claiming this is now debated by experts. In support of the premise that baseload supply won't be necessary in the future, he cites the "inherent storage capacity of EVs," the "shiftable thermal loads" in homes, businesses, and industrial plants, and the "potential capacity of back-up biofuels and various batteries."[33] His conclusion is that "we likely need less baseload power than people think and perhaps none at all."

Doubling down on this theme, Griffith points out that Japan and Germany both closed their nuclear units, while China is "slowing down on nuclear technology."[34] However, *Electrify* could have provided a fuller context in this regard. Japan's closure and safety review of all nuclear units following the 2011 Fukushima disaster, while comprehensive, was provisional: although many nuclear units were ultimately decommissioned, nine reactors at five locations had returned to commercial operation by March 2021.[35] Moreover, a government agency has observed that Japan will need to activate more nuclear capacity to displace its gas and coal-fired generation, if it is to achieve its goals under the Paris climate accord.[36] Germany, for its part, has encountered a range of reliability and economic challenges by following through with its controversial decision to dismantle its nuclear capacity, while resorting to more fossil fuel-burning capacity to supplement its large fleet of renewables. Finally, it would seem to bear mention that France and other European countries have not retrenched on nuclear generation.

Skeptic though he is, Griffith refrains from predicting the end of nuclear power. He predicts that (1) for "reasons of national security," the United States won't eliminate nuclear power; and (2) beyond U.S. borders, very densely populated nations – or those with a "lack of renewable resources" – will either have to avail themselves of nuclear or access renewable energy through imports.[37] He

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32. *Id.*

33. *Id.*

34. *Electrify*, *supra* note 1, at 71. To say China is "slowing down" would appear to be a stretch. A quick survey of online literature readily yields the information that China is emphasizing nuclear construction as a mean to diversify away from its current heavy reliance on fossil fuels, and has indicated its plans to build scores of new reactors as part of its commitment at the global climate change conference in Glasgow in 2021. *See* Wikipedia, *Nuclear power in China,* https:// en.wikipedia.org/wiki/Nuclear_power_in_China (as of Apr. 4, 2022, 15:15 GMT).

35. *See Japan's Nuclear Power Plants in 2021*, NIPPON (March 31 2021), https://www.nippon.com/en/japan-data/h00967//.

36. *See* Wikipedia, *Nuclear power in Japan*, en.wikipedia.org/wiki/Nuclear_power_in_Japan (as of Apr. 4, 2022, 15:15 GMT).

37. *Electrify, supra* note 1, at 71.

also keeps the door open a crack to decarbonizing technologies he doesn't think can stand on their own two feet at present. Perhaps liquified renewables or carbon sequestration, he allows, will eventually prove their worth, but starkly adds: "it's too late and too dangerous to rely on miracles."[38] Griffith closes the chapter with a gust of green-populist rhetoric, first lambasting those who contend, with "cynical and specious arguments" and "massive misinformation," that renewables can't "do it all," and then upbraiding "the state-sponsored utility monopoly which gives low interest rates to big projects instead of consumers who need to swap their gas heaters for solar and heat pump."[39]

III. RELIABILITY ROUND THE CLOCK

Given Griffith's dismissal of the idea that renewables can't do for the grid what baseload energy does, it's hardly surprising that he dedicates a chapter[40] to imagining reliability in a renewables-heavy environment. He begins by blasting "people who resist decarbonization" on grounds of reliability as "dinosaurs" who "often have vested interests."[41] Continuing in this mode, he touches on the "grand bargain" of the 20th century that gave utilities a monopoly in exchange for the understanding that service would be both continuous and affordable to the "under-served."[42] This "deal worked pretty well," he concedes, during the last century but accuses both "corporate utilities" and rural co-ops of having "a mixed bag of incentives" that prevent them from rapidly decarbonizing to address climate change.[43]

Griffith's focus then turns to a set of concepts he says will enable the grid to meet demand continuously despite relying to a much greater extent on "intermittent" resources. The keys lie in both ramping up, by a factor of "three to four times," the quantity of power generated and reimagining the grid:

"We won't do this by tuning up the old grid; it will require rebuilding the grid with new twenty-first century rules and internet-like technology."[44]

Griffith first describes the inherent lumpiness of residential loads, and acknowledges they will get even lumpier if, as he recommends, all forms of home energy consumption (plus transportation) are converted to electricity. He paints a picture of heavier demand in the morning, almost "no electricity" demand at 3 p.m., and a big surge in demand (including EV recharging) when the family returns home in the evening.[45] Finally, on the supply side, he sketches the

38. *Id.* at 72.

39. *Id*.

40. *Id.* at 75–95.

41. *Electrify, supra* note 1, at 76.

42. *Id.*

43. *Id.*

44. *Id.* at 77.

45. *Electrify, supra* note 1, at 78. Here, *Electrify* doesn't take account of the new stay-at-home patterns wrought by the pandemic for office workers; nor does such a simplified diurnal cycle seem to recognize that home heating or air-conditioning loads remain active in the afternoon, depending on the time of year, in most climates – though Griffith almost simultaneously acknowledges "thermal [electric] loads are big and heavy."

natural daily and seasonal variabilities of wind and solar energy production before asking how all these load and supply swings can be matched up.

The solution, according to Griffith, lies in creating "lots of storage" for renewable energy.[46] This is nothing new for the energy industry writ large, he points out, noting the substantial amounts of storage for natural gas and oil in the United States as well as the coal piles beside coal-fired generation plants.[47] Chemical battery storage, while "quite expensive," he admits, is falling in cost rapidly, and "large-scale deployment . . . is becoming a realistic possibility."[48] But the hitch, he proceeds to relate, is that batteries are suited to "ironing out" hourly or diurnal variations, not acting as longer-term storage reservoirs, as they are too costly; still, he foresees a time in the not-too-distant future when domestic battery storage coupled with rooftop solar will beat the current cost of utility-grid electricity.[49]

The chapter goes on to survey other types of energy storage – battery or otherwise. The former is represented mainly by EVs serving as supplemental batteries to feed the grid (Griffith envisions hundreds of millions of EVs doing this, providing a major new supply source, once the U.S. transportation fleet is converted to electric). Other types are "thermal storage," pumped hydro storage, and an assortment of other technologies Griffith does not regard as ready for prime time.[50] Finally, the author raises biofuels – from wood to agriculture waste to sewage – as surrogates for batteries to "bridge seasonal gaps . . . ."[51]

Returning to demand management, Griffith also suggests running big factory loads in the daytime to take advantage of the new abundance of solar energy, observing: "We reacted to cheap power at night by creating night shifts in heavy industry so that industry could consume that power," but in a "solar- and wind-powered world, we will have the opportunity to rethink some of these decisions."[52] However, readers might pause on the notion that night shifts were created to take advantage of cheaper power. While it is a bonus in places where time-of-day rates are in effect (or special contracts were negotiated), heavy, capital-intensive industries with 24-hour shifts and continuous production are mainly set up that way to reduce unit costs by averaging fixed costs over as many units as possible. In addition, some major industrial processes lend themselves to continuous operation rather than cycling up and down.[53] Also, Griffith probably overstates the flexibility of manufacturers to shift production schedules around to

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46. *Id.* at 83.

47. *Id.*

48. *Id.*

49. *Electrify, supra* note 1, at 84.

50. *Id.* at 84–85. It is less than clear in this chapter how thermal storage works as electricity storage, unless Griffith is merely talking about incentives for demand interruption and load shifting. A few pages later, the author discusses "demand response" as a methodology for managing load and supply mismatches.

51. *Id.* at 86.

52. *Id.* at 87.

53. This reviewer is familiar with the aluminum industry, for example, which is designed for continuous production. The industry negotiates for lower-cost power associated with round-the-clock service and can withstand some temporary interruptions, but not for many hours at a time. A cloudy day resulting in an extended shortage of solar energy could be a disaster for an aluminum smelter.

better synch up with the ebbs and flows of intermittent generation when he asserts: "Manufacturers can still produce the same amount of goods in the long-term, but they can match their major loads to the available energy supply over time."[54]

To bring off such a future grid predicated on all (or largely) intermittent renewables, Griffith, as might be expected, also calls for constructing a great deal more transmission infrastructure – most critically, to take advantage of interregional wind and solar diversities.[55] He further advocates – as a self-styled "radical" idea – going overboard in the amount of solar and wind capacity to be developed, with a view to satisfying even winter peaks (when a renewables-only system is strained for capacity as solar availability wanes, just as heating and lighting demands increase). Griffith offers two rationales to buttress his "radical" proposal: first, that the incremental cost of building extra wind and solar to meet the winter peak would be cheaper than the alternative of constructing sufficient battery storage; [56] and second, that the resulting summertime solar surplus could be put to good use "in the production of hydrogen or ammonia or even the scrubbing of carbon from the atmosphere" (*i.e.,* carbon sequestration) – strategies he's previously relegated to the impracticable or improbable.

IV. HOME IS WHERE THE INFRASTRUCTURE IS

Electrify has much to say about the cost and financing of top-to-bottom decarbonizing of households and driveways. From universal rooftop solar to electric furnaces and water heaters, Griffith envisions a massive replacement cycle along with, not coincidently, an employment boom and attendant prosperity in all corners of the economy. One of his fundamental precepts is that our understanding of "infrastructure" must be expanded to encompass these new, all-electric home devices, battery storage and EVs included.[57]

Labeling such home equipment as "infrastructure" is Griffith's stepping-stone to urging adoption of expansive new public policies to finance their purchase. Federal loan guarantees and subsidies to homeowners (and to landlords, where homes are not individually owned) are critical catalysts in making the replacement cycle affordable. Throughout the book, Griffith likens the decarbonization of the economy to a war effort, so recharacterizing energy devices in homes as semi-public infrastructure enhances the theme: *i.e.,* it is the duty of government in public emergencies to drive mobilization and lead change.[58] With his typically cheery air, he writes:

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54. *Electrify, supra* note 1, at 87.

55. *Id.* at 90–91.

56. *Id.* at 93. Notably, Griffith uses a hypothetical production cost for wind/solar of just 2-4 cents per kwh – which seems on the low end even for utility-scale solar, and does not account for incremental transmission investment costs.

57. *Id.* at 98–101.

58. Later in the book Griffith includes an entire chapter – "Mobilizing for World War Zero" – to embellish the point, lest it's been lost on readers thus far. *Electrify, supra* note 1, at 163–72.

"Redefining infrastructure allows us to contemplate the intriguing notion that the United States might be just an interest rate away from a climate cure . . . .[L]owest-cost infrastructure-grade financing is crucial."[59]

In the ensuing chapter (Chap. 10, "Too Cheap to Meter"), Griffith goes into detail to make his pitch that, with today's technology, utility-scale solar and wind generation already outcompete natural gas and coal power from a cost perspective.[60] But Griffith's ultimate quest is to convince readers that *virtually every roof in America* should be fitted with solar panels, to attain even greater savings than utility-scale renewables can offer. His vision is encapsulated in this excerpt:

"Here is the transformative point about rooftop solar: because there are no transmission and distribution costs, it can be phenomenally cheap. Even if the cost of utility-scale generation were free, we don't know how to transmit it to you and sell it to you for less than the cost of rooftop solar. This doesn't mean the whole world will run on solar and distributed resources, but it does mean that if we are looking to make the lowest-cost energy system, an awful lot of America's energy will come from our rooftops and our communities."[61]

The chapter goes on to sketch how the costs of wind and solar generation have fallen precipitously in recent years, projecting that they will tumble even further, "likely halv[ing] the cost of renewables again – a nail in the coffin of fossil fuels."[62]

In his clincher chapter, "Bringing it all Home,"[63] Griffith rolls out an elaborate modeling effort to demonstrate how a big capital expenditure program with low-cost financing to equip homes for maximum renewable energy production and usage would, in the long run, "save us all money" versus the status quo.[64] The chapter is informative in depicting the full spectrum of household costs, where energy fits into the total budget, and the extent to which energy costs might be driven down by full adoption of the book's recommendations.[65] Griffith's rollup of the data projects that rooftop solar ought to cover about 75% of total home energy needs; and, figuring a long-term cost of 5 cents/kWh for this home-generated energy (based on financing costs of 2.9%) while assuming a na-

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59. *Id.* at 101.

60. *Id* at 104ff. Generation cost comparisons are always a complicated subject, and highly dependent on assumptions. An immediate observation is that the comparison in the subject chapter uses "levelized cost of energy" for wind, solar, and fossil-fuel capacity. But a great deal of natural gas and coal-fired capacity is already built and in service; hence, their variable operating cost is relevant to a comparison as well.

61. *Id* at 105.

62. *Electrify, supra* note 1, at 71, at 109. Griffith neglects to mention that much of the reductions in solar costs have come from China's takeover of the industry. *See,* DANIEL YERGIN, THE NEW MAP 396-97 (2020) 96–97 *(*reporting that almost 70% of solar panels are made in China; over 80% by Chinese companies within or outside China, and that almost 95% of the solar wafers that are the heart of panels are produced there). Yergin notes that "the cost of solar panels came down by an extraordinary 85% between 2010 and 2019, driven mainly by Chinese manufacturing and massive capacity and by technical improvements" as well as by what a renewables advocacy organization has labeled "cutthroat pricing" thanks to China's overcapacity. *Id* at 397–98.

63. *Electrify, supra* note 1, at 112–29 (Chapter 10).

64. *Id.* at 112.

65. The chapter even contains a chart depicting state-by-state household use of energy, broken down by fuel source. *Id.* at 116.

tional average cost of 14 cents per kWh for utility-delivered electricity, Griffith emerges with an estimated annual savings per household of *at least* $1000 and "if we do very well," $2500.[66]

Necessarily, any such modeling is chock-full of assumptions. Griffith allows that his assumptions are "aggressive," but "not without precedent."[67] What may leave readers scratching their heads is what happens to the transmission and distribution costs the book recognized are big ticket items in the cost of delivered energy, not to mention the fixed costs of maintaining central stations at the ready. Griffith apparently leaves these costs off the books when it comes to figuring out the purportedly massive end-user savings.[68] But distributed energy owners still depend on the grid for backup – *i.e.,* nocturnal or cloudy-day energy – unless they're prepared to decouple and rely on their EV batteries (or fossil-fuel home generators) to carry them through sunless hours. But even Griffith does not go that far.

Griffith's argument for major government involvement in financing the electrification of homes and cars also draws on "climate justice" considerations. He fairly points out that the wealthy can best afford the "upfront capital costs" of rooftop solar, EVs, and other decarbonizing gadgets because "they have access to easy credit and home equity loans."[69] Indeed, some well-heeled Americans can afford to pay for their luxury EVs out of savings and cashflow. Yet, as the author points out, the low-income segment of the population would benefit the most from any cost savings attributable to electrification. And obviously, a mass conversion to all-electric domestic and transportation systems requires a "no household left behind" approach. Hence, Griffith seizes the moment of "historically low interest rates," coincident with the 2020-21 pandemic, to "finance the household technology and infrastructure that will decarbonize our future lifestyles."[70]

V. COMPENSATING THE LEGACY ENERGY COMPANIES

Perhaps surprisingly, given Griffith's frequent expressions of scorn for the "fossil fuel industry," *Electrify* proposes a compensation package for the "stranded assets" of legacy hydrocarbon companies. To do otherwise, he posits, would invite the kind of financial calamity the United States (and much of the developed world) experienced during the mortgage market crisis and stock market crash of 2008. "Clearly," he states, "we can't just pull the rug out from underneath the industry that gave us modernity. We need a plan."[71]

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66. *Id.* at 121–22.

67. *Electrify, supra* note 1, at 121–22.

68. In addition to the "transformative point" quote above (*Id.* at 105), Griffith stresses (*Id.* at 104) that even the "impressively low" costs of utility-scale solar can be beaten with home generation: "Oddly, though, rooftop solar can be even cheaper because if you're generating electricity yourself, you don't have to pay for distribution." *Id.*

69. *Id.* at 125.

70. *Id.* at 129. Readers in 2022 will note, however, that the near-zero interest rates Griffith invokes are transitioning towards higher rates as inflation become a prevailing concern.

71. *Electrify, supra* note 1, at 133.

The author tosses out some assumptions about the profit margins for proven reserves (figures that are not necessarily compensatory, given the dramatic rise in oil and gas prices since mid-2021), and comes up with a multi-trillion-dollar buyout hypothesis. The section is far from fleshed out; it is more like a gesture – an opening bid in an imaginary negotiation – and it's not clear either who exactly would *pay* the trillions or whether international and state-owned energy companies (*e.g.,* Russian, Saudi, and Venezuelan companies) would *receive* payouts, or whether the rescue package would be limited to Western democracy companies.

It's also less than clear regarding the time frame in which the fossil fuel companies would be bought out. Elsewhere, *Electrify* implies what amounts to a gradual phase-out, with those new, "clean energy" machines being purchased when the older ones reach the end of their useful lives.[72] That could take decades. Yet, in the chapter on industry compensation, while applauding the spirit behind "divestment" campaigns to "slowly starve the fossil fuel industry of the precious capital they need," the author argues that the strategy is too slow to be effective in light of "the urgency and inevitability of climate change . . . ."[73]

In a chapter of particular interest to the regulatory community ("Rewrite the Rules!"),[74] Griffith surveys the diverse field of federal and local laws and regulations and declares them largely unsuited to expediting the transition to a clean energy world. The chapter touches on numerous aspects, from construction codes to ratemaking, and notably takes aim at "net metering" – generally thought of as a boon to home solar generators – as *not* "good enough," because customers offering up excess energy to the grid are only offered the wholesale, not the retail, value of their kWh. Likewise, time-of-use pricing "isn't good enough either" in Griffith's judgment because "not everyone has that choice" of when to consume.[75]

Instead, Griffith advocates a construct he calls "grid neutrality," which he evidently sees as democratizing the power system, much like the internet has done for information and trade.[76] Under this scheme, households, like utilities, could buy and sell energy to each other. The public utilities, he admits, "don't love this idea, especially those that are also trying to protect their natural gas business," but such patent self-interest should not, in Griffith's view, intimidate the public from imposing more forward thinking:

"But remember that 'we the people' regulate the utilities, so we don't need to fear them. We can control them; we just need to express our collective will."[77]

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72. See e.g. where Griffith argues that the government's payout for the cost for the transition would "only amount to about $300 billion per year for the 15 years of mobilization." *Id.* at 154, or where Griffith suggests the large sticker price for the Green New Deal should be put in perspective: " . . . this amount will be spread out over 15-20 years. This is mostly spending the country was going to do anyway – everyone is going to buy a new car or two in that 20 years, and appliances, and home retrofits . . . ." *Id* at 153.

73. *Id.* at 133–34.

74. *Id.* at 137–44.

75. *Electrify, supra* note 1, at 142.

76. *Id.* at 143–44.

77. *Id.* at 143.

VI. CONCLUSION

Griffith is not the most objective of guides. In a field generally calling for empiricism, balance, conservative assumptions, and sober judgments, he frequently comes off as a cheerleader and prophet for a movement he regards as literally world-saving. The earnestness and passion he brings to the task seem genuine. And it helps that, even as *Electrify* burrows into the technical and policy-wonkish depths of its material, Griffith's writing style is commendably clear and easy-going – frequently jokey and sometimes even profane – as he strives to lighten the mood and forge a camaraderie with his readership.

Occasionally, Griffith simply gets things wrong. He inexplicably refers to the "2016 [sic] Paris Agreement to avert climate crisis."[78] In his chapter about preparing for "war," he tells us that in 1939, the "mood of the country, particularly among the New Deal Democrats, was against intervening in international affairs." While the sentiment against getting involved in Europe in the late 1930s had both left- and right-wing adherents, President Roosevelt – the leader of the New Deal – sought *more* involvement, as he navigated the political headwinds against actively assisting the Allies.[79] Griffith's chapter kindling enthusiasm for an explosion of government expenditures to address unemployment and lift the country out of a recession[80] seems almost quaint in early 2022, as unemployment is low, good jobs go begging, and inflation (partly from government stimuli) is a real concern. In an appendix,[81] Griffith takes hard sideswipes at carbon sequestration and use (even as an adjunct to burning carboniferous fuels) as well as denouncing fracking and natural gas – all 21st century energy mainstays (or in the case of carbon sequestration, a promising frontier technology).[82]

Two major caveats should be kept in mind. First, Griffith is a scientist and engineer, but not a climate scientist, and does not attempt to reexamine the mainstream consensus on GHG. Rather, he wholeheartedly embraces its most dire predictions, using them as a springboard for challenging the incumbent energy industry to accept a raft of changes. Second, Griffith's analysis and prescriptions for reform are targeted expressly for the United States. Although climate change is obviously a worldwide issue, the rest of the globe only comes in for only glancing attention; his premise is that if the United States cleans up its act, the rest of the world will follow. Whether that premise holds water is a question readers can contemplate for themselves.

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78. *Id.* at 14. The agreement was struck in December 2015.

79. Conversely, Senator Robert Taft, a prominent Republican leader, ardently opposed any United States involvement in the conflict in Europe, up until the bombing of Pearl Harbor in December 1941, though Taft's isolationism drew cross-fire from liberal Republicans. *See generally* SARAH CHURCHWELL, BEHOLD, AMERICA (2018), for an account of United States support for, or tolerance of, Fascist regimes in Europe in that era.

80. *Electrify, supra* note 1 at 145–61 (Chapter 15: "Jobs, Jobs, Jobs").

81. *Id.* at 193–94.

82. See Yergin, *supra* note 62, at 405 ("The 2015 Paris climate compact provided new impetus to develop 'carbon capture and storage,' or CCS. Around the same time, a "U" for "use" was added to the acronym . . . .CCUS takes many forms today. For instance, captured carbon is being used to manufacture products like cement and steel. 'Direct air capture' – pulling CO2 out of the air – had seemed fanciful, but progress is being made and units are being scaled up.")

For those already inclined to accept that climate change is mankind's most forbidding challenge, the author's absolutism and devotion to radical action will prove stimulating. His remedial strategies, tinged with a sunny optimism, will equip persuaded readers to enter the fray with specific concepts, along with arm-loads statistics and graphs. On the other hand, energy pragmatists and climate change skeptics should find the volume of use as a compendium of positions green energy advocates will stake out in public forums, so they might as well get more familiar with them.