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Clean Food: The Next Clean Energy Revolution

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The world is in the throes of a clean energy revolution. This revolution has led to the ongoing demise of coal, and a shift towards clean and efficient energy sources like wind and solar. Despite these advances, the process of producing food for human energy remains extraordinarily dirty and inefficient. This Essay explores what it would look like to graft clean energy policy onto the human food system. It discusses what is wrong with the standards by which we currently evaluate food policy and how we might apply a clean human energy or “clean food” standard instead. It concludes that building a clean food grid should be the next clean energy revolution.

INTRODUCTION

Locating and consuming energy is a fundamental priority for every living organism. Even autotrophs must have access to light, organic nutrients, or other elements in order to carry out the biological miracle of creating their own food.¹ Energy is the key ingredient that makes everything and everyone function in the world. Over the last decade, the process of manufacturing and using me-

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1. See Jonathan R. Leake, Duncan D. Cameron & David J. Beerling, *Fungal Fidelity in the Myco-Heterotroph-to-Autotroph Life Cycle of Lycopodiaceae: A Case of Parental Nurture?*, 177 NEW PHYTOLOGIST 572-76 (2008).

chanical energy has been in the throes of a massive revolution.² Today, mechanical energy is judged by two primary criteria: cleanliness and efficiency.³ When policymakers talk about clean energy, they mean far more than “sanitary”—looking instead at the full range of environmental externalities associated with harnessing, processing, and transporting various energy sources.⁴ When they talk about energy efficiency, the key question is the relative rate of loss or waste as one form of energy is converted to another—like burning coal to create electricity.⁵ Thus, a particular energy system can be both clean and efficient (wind turbines), clean but inefficient (outdated solar panels), dirty but efficient (fracking), or dirty and inefficient (internal combustion engines). This new focus on clean and efficient energy has led to the ongoing demise of coal,⁶ and the rapid expansion of clean and efficient new energy sources like wind and solar.⁷

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2. See Varun Sivaram & Teryn Norris, *The Clean Energy Revolution: Fighting Climate Change With Innovation*, FOREIGN AFF. (Apr. 18, 2016), <http://www.foreignaffairs.com/articles/united-states/2016-04-18/clean-energy-revolution> [http://perma.cc/J53H-QJGD]; Allison Lantero, *Meet the Women Leading the Clean Energy Revolution*, U.S. DEP’T ENERGY (May 2016), <http://www.energy.gov/articles/meet-women-leading-clean-energy-revolution> [http://perma.cc/G5AQ-EUJ9].
 3. See *Energy Partners Launch ‘Clean and Efficient Energy Program’ for Public Power*, ALL. TO SAVE ENERGY (Feb. 23, 2009), <http://www.ase.org/news/energy-partners-launch-clean-and-efficient-energy-program-public-power> [http://perma.cc/P3AZ-4VPB]; Horizon 2020, *Secure, Clean and Efficient Energy*, EUR. COMM’N (2013), <http://ec.europa.eu/programmes/horizon2020/en/h2020-section/secure-clean-and-efficient-energy> [http://perma.cc/4KQW-9DRE]; *Affordable Access to Clean and Efficient Energy: Final Working Group Report*, MASS. DEP’T OF ENERGY RES. & DEP’T OF HOUS. & CMTY. DEV. & MASS. CLEAN ENERGY CTR., (Mar. 4, 2017), <http://www.mass.gov/files/documents/2017/09/12/aacee-report.pdf> [http://perma.cc/2TLY-PAAQ].
 4. See, e.g., Dora E. López, Joseph C. Mullins & David A. Bruce, *Energy Life Cycle Assessment for the Production of Biodiesel from Rendered Lipids in the United States*, 49 INDUS. ENGINEERING CHEMISTRY RES. 2419 (2010).
 5. Yuan Xu, Chi-Jen Yang & Xiaowei Xuan, *Engineering and Optimization Approaches to Enhance the Thermal Efficiency of Coal Electricity Generation in China*, 60 ENERGY POL’Y 356 (2013).
 6. See THOMAS PRINCEN, JACK P. MANNO & PAMELA L. MARTIN, *ENDING THE FOSSIL FUEL ERA* (2015); Karen Heller, *Coal No Longer Fuels America. But the Legacy—and the Myth—Remain*, WASH. POST (July 9, 2017), http://www.washingtonpost.com/lifestyle/style/coal-no-longer-fuels-america-but-the-legacy--and-the-myth--remain/2017/07/07/d8a8bcb4-582b-11e7-b38e-35fd8e0c288f_story.html [http://perma.cc/ZWE2-NMVM].
 7. See BEN BACKWELL, *WIND POWER: THE STRUGGLE FOR CONTROL OF A NEW GLOBAL INDUSTRY* (2015); Ernest Moniz, *A Clean Energy Revolution—Now*, U.S. DEP’T ENERGY (Sept. 19, 2013), <http://www.energy.gov/articles/clean-energy-revolution-now> [http://perma.cc/UP45-5M7G].

Clean human energy or “clean food”⁸ is the last frontier of the clean energy revolution. The current food system is extraordinarily dirty and inexcusably inefficient.⁹ Yet, the two key criteria for judging mechanical energy in policy circles—cleanliness and efficiency—are rarely applied to human energy sources. This is unusual, as food is, at its core, nothing more than biological energy. In a world headed for more than nine billion mouths to feed by 2050,¹⁰ the food system should be held to the same standards of cleanliness and efficiency as other energy sources. Those human energy sources that meet the clean and efficient mandate should flourish, and those that do not are likely to find themselves the “food coal” of the next decade.

Despite its first order of importance to all human endeavors, the legal scholarly attention to the issue of food policy is shockingly lean. A quick survey of legal scholarship between 2000 and 2014 reveals more than 22,000 published works concerning free speech.¹¹ By comparison, just 430 works concerning food policy were produced during this same time frame.¹² Among those latter works,

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8. The terms “clean” and “dirty” are sometimes used narrowly to describe the relative level of sanitation or purity of food items. See, e.g., Andrew Wasley, ‘Dirty Meat’: Shocking Hygiene Failings Discovered in US Pig and Chicken Plants, *GUARDIAN* (Feb. 21, 2018), <http://www.theguardian.com/animals-farmed/2018/feb/21/dirty-meat-shocking-hygiene-failings-discovered-in-us-pig-and-chicken-plants> [<http://perma.cc/5AX4-YNTB>]. The construction of “clean food” discussed herein is intended to be much broader, and serve as a policy analog to “clean energy.”
 9. See Gregory A Keoleian & Martin C. Heller, *Greenhouse Gas Emission Estimates of U.S. Dietary Choices and Food Loss*, 19 *J. INDUS. ECOLOGY* 391, 391 (2015) (“Globally, direct emissions from agriculture represent 10% to 12% of overall greenhouse gas (GHG) emissions; when including the impact of fertilizer and chemical production, fuel use, and agriculturally induced land-use change (which carries large uncertainty), the figure rises to 17% to 32%.”); Peter Alexander et al., *Losses, Inefficiencies and Waste in the Global Food System*, 153 *AGRIC. SYSTEMS* 190, 193 (2017) (“Only 19.2-31.9%—less than a third—of biomass harvested from crops or grass is finally consumed by humans.”).
 10. See Food & Agric. Org., *The State of the World’s Land and Water Resources for Food and Agriculture: Managing Systems at Risk*, UNITED NATIONS (2011), <http://www.fao.org/docrep/017/i1688e/i1688e.pdf> [<http://perma.cc/S98J-3C24>]; Associated Press, *UN: Farmers Must Produce 70% More Food by 2050 to Feed Population*, *GUARDIAN* (Nov. 28, 2011), <http://www.theguardian.com/environment/2011/nov/28/un-farmers-produce-food-population> [<http://perma.cc/6QSA-3G38>] (“The UN Food and Agriculture Organisation (FAO) estimates that farmers will have to produce 70% more food by 2050 to meet the needs of the world’s expected 9-billion-strong population.”).
 11. See Hollis, HARV. UNIV., <http://hollis.harvard.edu/> [<http://perma.cc/3RVK-MH98>] (last visited Mar. 29, 2018) (searching for “free speech” in U.S. academic law journals 2000-2014).
 12. See Baylen Linnekin & Emily Broad Leib, *Food Law & Policy: The Fertile Field’s Origins and First Decade*, 2014 *WIS. L. REV.* 559, 597.

precious few advocate for the codification of any kind of individual right to engage in humans' most basic biological function at either the state, federal, or international level.¹³ The United Nations has explored the development of a right to food, but to date nothing concrete has come of these explorations.¹⁴ In keeping with the food-privileged status of the legal academy, it appears we spend infinitely more time fretting over legal protections for what comes *out* of people's mouths than we do thinking about how to ensure there is something to go *in*.

The purpose of this Essay is to explore what it would look like to graft the policy yardstick of modern mechanical energy cleanliness and efficiency onto the human energy system. What is wrong with the way we currently evaluate food policy? And what would it look like to apply a clean food standard instead? The thesis of this Essay is that by shifting the way we conceptualize food—and embracing a new clean and efficient human energy standard—we can more objectively consider both old and new potential solutions to “power” the hundreds of millions of people who currently lack food security in the world,¹⁵ and better ensure ample human energy is available for the billions of new human energy consumers joining our ranks by 2050.

I. THE CLEAN ENERGY REVOLUTION

When Congress overhauled and expanded the federal Clean Air Act in 1970 to impose the first meaningful protections against domestic air pollution,¹⁶ roughly seventy percent of the world's energy production came from just two sources: petroleum and coal.¹⁷ The inefficiency, waste, and pollution associated

13. See, e.g., Paul A. Diller, *Combating Obesity with a Right to Nutrition*, 101 GEO. L.J. 969 (2013).

14. See Olivier De Schutter, *Final Report: The Transformative Potential of the Right to Food*, UNITED NATIONS HUM. RTS. COUNCIL (Jan. 24, 2014), http://www.ohchr.org/EN/HRBodies/HRC/RegularSessions/Session25/Documents/A_HRC_25_57_ENG.DOC [<http://perma.cc/U3WH-EP8J>].

15. See THOMAS J. BASSETT, *THE ATLAS OF WORLD HUNGER* (2014) (“In 2006, the Food and Agricultural Organization of the United Nations counted 850 million hungry people worldwide . . .”); *World Hunger Again on the Rise, Driven by Conflict and Climate Change, New UN Report Says*, WORLD FOOD PROGRAMME (Sept. 15, 2017), <http://www.wfp.org/news/news-release/world-hunger-again-rise-driven-conflict-and-climate-change-new-un-report-says> [<http://perma.cc/EN83-JW4H>].

16. See Clean Air Act Extension of 1970, Pub. L. No. 91-604, 84 Stat. 1676 (1970).

17. See *World Energy Balances 2017: Overview*, INT'L ENERGY AGENCY 5 (2017), <http://www.iea.org/publications/freepublications/publication/WorldEnergyBalances2017Overview.pdf> [<http://perma.cc/868A-MH4C>]:

Between 1971 and 2015, world total primary energy supply (TPES) multiplied by almost 2.5 times and also changed structure somewhat . . . While remaining the dominant fuel in 2015, oil fell from 4% to 32% of TPES. The share of coal has increased constantly since 1999, influenced primarily by increased consumption in China, and reached its highest level since 1971 in

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with these fuel sources are all extraordinarily high. An automobile internal combustion engine converts just twenty to twenty-five percent of the fuel it burns, with a theoretical limit of approximately fifty-six percent.¹⁸ Coal-fired power plants are also notoriously inefficient, with every railcar of coal generating an average of thirty-four percent of its energy into usable power,¹⁹ and emitting 186 metric tons of CO₂.²⁰

For decades, policymakers worked around the edges of these inherently dirty and inefficient energy technologies, trying to make them slightly less problematic. The Clean Air Act and Title IV of the 1990 amendments to the Act put meaningful limits on air pollution from most coal- and petroleum-burning energy sources,²¹ which in fairness did result in significant reductions in overall air pollution and some increases in efficiency.²² For example, between 1975 and 2012, the average fuel economy of passenger cars increased from approximately twenty miles per gallon to thirty-four miles per gallon.²³

2011 (29.1%) It has started declining since then and represented 28% in 2015. Meanwhile natural gas grew from 16% to 22% and nuclear from 1% to 5%.

18. See Bertel Schmitt, *The Internal Combustion Engine Will Survive Us All*, FORBES (July 20, 2017), <http://www.forbes.com/sites/bertelschmitt/2017/07/20/the-internal-combustion-engine-will-survive-us-all> [<http://perma.cc/SA8H-27GA>] (“[T]he typical gasoline automobile engine operated at around 25% efficiency. The theoretical maximum efficiency of a gasoline engine is said to be at around 56%.”); M. Miller, A. Holmes, B. Conlon & P. Savagian, *The GM “Voltec” 4ET50 Multi-Mode Electric Transaxle*, 4 SAE INT’L J. ENGINES 1102-14 (2011); *All Electric Vehicles*, U.S. DEP’T ENERGY, <http://www.fueleconomy.gov/feg/evtech.shtml> [<http://perma.cc/66WU-PRPQ>] (last visited Mar. 28, 2018).
19. See Xiaochun Zhang, Nathan P. Myhrvold & Ken Caldeira, *Key Factors for Assessing Climate Benefits of Natural Gas Versus Coal Electricity Generation*, 9 ENVTL. RES. LETTERS 114022 (2014) (“The coal power plant thermal efficiencies in this database range from 23% to 51%, and the value for a world typical coal plant is 34%.”).
20. See *Greenhouse Gas Equivalencies Calculator*, U.S. ENVTL. PROT. AGENCY (Sept. 2017), <http://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator> [<http://perma.cc/6S2M-WEQ7>].
21. See Clean Air Act Amendments of 1990, Pub. L. No. 101-549, 104 Stat. 2468 (1990).
22. See generally Winston Harrington, Richard Morgenstern, Jhih-Shyang Shih & Michelle L. Bell, *Did the Clean Air Act Amendments of 1990 Really Improve Air Quality?*, 5 AIR QUALITY, ATMOSPHERE & HEALTH 353 (2012); *The Benefits and Costs of the Clean Air Act 1990-2020*, U.S. ENVTL. PROT. AGENCY (Apr. 2011), http://www.epa.gov/sites/production/files/2015-07/documents/fullreport_rev_a.pdf [<http://perma.cc/HLH9-LD9M>].
23. See *Fuel Economy Standards Have Affected Vehicle Efficiency*, U.S. ENERGY INFO. ADMIN. (Aug. 3, 2012), <http://www.eia.gov/todayinenergy/detail.php?id=7390> [<http://perma.cc/VQR6-K483>]; *History of Fuel Economy: One Decade of*

Despite these modest successes, an entirely new approach to making energy more clean and efficient has taken hold in the last decade. Rather than continuing to retrofit inherently inefficient and dirty technologies like coal and petroleum, forward-thinking policymakers, corporations, and investors have ramped up the development and deployment of new, high-efficiency, low-pollution alternative-energy technologies like wind, solar, and geothermal to replace aging and outdated coal and petroleum-based energy sources.²⁴ At the same time, rather than continuing to focus on squeezing a few more miles per gallon from internal combustion engines, or slightly more efficiency from incandescent lightbulbs, the focus of energy policymakers and advocates has shifted to the expansion of electric vehicles, LED lightbulbs, and other technologies that provide exponential rather than incremental increases in energy efficiency.²⁵

This clean energy revolution is still ongoing, and by no means universally embraced.²⁶ For every corporation, public policymaker, and investor that has embraced a transition to clean energy, an equal number seem to have clung to outmoded, inefficient, and polluting technologies, and stubbornly insisted that they can be modified to be more socially acceptable. The most striking example is the coal industry's "clean coal" campaign, which has done herculean work to convince the public that the industry can be retrofitted to fit into the clean energy revolution.²⁷

Innovation, Two Decades of Inaction, PEW CHARITABLE TR. (Apr. 2011), <http://www.pewtrusts.org/~media/assets/2007/05/01/history-of-fuel-economy.pdf> [<http://perma.cc/5W8H-L7Q3>].

24. See NRDC Report: *Clean Energy Revolution Shatters Records & Projections*, NAT. RES. DEF. COUNCIL (Oct. 3, 2017), <http://www.nrdc.org/media/2017/171003-0> [<http://perma.cc/G7JT-APVZ>] (describing "massive shifts in the nation's energy landscape, dominated by clean energy progress, both with records shattered in the past year and a half and from what the U.S. Energy Information (EIA) projected a decade earlier").

25. See Moniz, *supra* note 7:

In recent years, costs for numerous critical clean energy technologies—wind power, solar panels, super energy-efficient LED lights and electric vehicles—have fallen significantly. The accompanying surge in deployment has been truly spectacular. Such a surge is tantamount to topping the barricades—a level of cost reduction and market penetration that will enable a full scale revolution in the relatively near term.

26. See Ari Rabl & Joseph Spadaro, *External Costs of Energy: How Much Is Clean Energy Worth?*, 138 J. SOLAR ENERGY ENGINEERING 040801 (2016); Chris Dalby, *The Dirty Truth About Clean Energy*, OILPRICE.COM (June 28, 2014), <http://oilprice.com/Energy/Energy-General/The-Dirty-Truth-About-Some-Clean-Energy.html> [<http://perma.cc/8GEU-KU6N>].

27. See, e.g., *High Efficiency Low Emission Coal*, WORLD COAL ASS'N (2017), <http://www.worldcoal.org/reducing-co2-emissions/high-efficiency-low-emission-coal> [<http://perma.cc/T4CW-5LDU>] (promising to improve "the current average

The entire public relations and technological effort for clean coal has failed miserably.²⁸ Not only are the campaign's assertions overblown, but the concept is simply too little, too late.²⁹ Driven by increasingly dire concerns about climate change and other risks, plants have closed and major investors have walked away from coal in recent years, leaving industry with little choice but to wait for its inevitable demise and replacement.³⁰ Even a massive deregulatory push by the Trump administration has done little to increase coal's long-term outlook.³¹

global efficiency rate of coal-fired power plants from 33% to 40%—i.e., reducing waste from sixty-seven percent to sixty percent).

28. See Richard Conniff, *The Myth of Clean Coal*, YALE ENV'T 360 (June 2, 2008), http://e360.yale.edu/features/the_myth_of_clean_coal [<http://perma.cc/D788-Z7N9>] (“The coal industry and its allies are spending more than \$60 million to promote the notion that coal is clean. But so far, ‘clean coal’ is little more than an advertising slogan.”); Jeff Goodell, *The False Promise of Clean Coal*, POST CARBON INST. (2013), http://energy-reality.org/wp-content/uploads/2013/06/17_False-Promise_R1_042413.pdf [<http://perma.cc/N577-FMCV>] (“The coal industry’s slick advertisements promoting ‘clean coal’ employ twenty-first century media techniques to keep us locked into a nineteenth century energy economy. A classic greenwashing campaign, it uses the iconography of sexy technology and down-home Americana to maintain the status quo: Big Coal’s influence over energy politics.”).
29. See *Carbon Capture Analyst: ‘Coal Should Stay in the Ground’*, MICH. NEWS (Dec. 2, 2015), <http://news.umich.edu/carbon-capture-analyst-coal-should-stay-in-the-ground/> [<http://perma.cc/T9FZ-TB2N>] (“U-M researchers have found that most economic analysis of carbon capture and storage, or CCS, technology for coal-fired power plants severely underestimates the technique’s costs and overestimates its energy efficiency.”); Gabe Elsner, *Southern Company’s Kemper Scandal and Why Carbon Capture and Storage (CCS) Will Never Work*, HUFFINGTON POST (2017), http://www.huffingtonpost.com/entry/southern-companys-kemper-scandal-and-why-carbon-capture_us_5784fc2de4b09c5504c41cd3 [<http://perma.cc/VHD6-G7ND>] (“Despite billions of dollars that have been spent to advance the technology, at least 33 power plant CCS projects have been scrapped or mothballed in the past five years In reality, wind and solar are more effective investments to produce carbon-free electricity in the 21st century.”); see also Sarang D. Supekar & Steven J. Skerlos, *Reassessing the Efficiency Penalty from Carbon Capture in Coal-Fired Power Plants*, 49 ENVTL. SCI. & TECH. 12576 (2015).
30. See, *Energy Darwinism II: Why a Low Carbon Future Doesn’t Have to Cost the Earth*, CITI GLOBAL PERSP. & SOLUTIONS (Aug. 2015), <http://ir.citi.com/E8%2B83ZXr1vd%2Fqyim0DizLrUxw2FvuAQ2jOlmkGzr4ffw4YJCK8s0q2W58AkV%2FypGoKD74zHfji8%3D> [<http://perma.cc/N5V9-9PPK>] (“[W]e think thermal coal is cyclically and structurally challenged and that current market conditions are likely to persist [T]he large diversified mining companies such as Rio Tinto, Anglo American and BHP Billiton have either been exiting thermal coal operations or significantly rationalizing their businesses.”); Katie Fehrenbacher, *Divesting from Coal is Becoming More Mainstream and It’s About Risk*, FORTUNE (June 6, 2015), <http://fortune.com/2015/06/06/divesting-from-coal/> [<http://perma.cc/82PV-PG2A>] (“[T]here are as many as 200 organizations that

The key lesson from the clean energy revolution is that after an initial period during which existing inefficient and dirty energy systems are modified, retrofitted, and cleaned up to provide incremental improvements, there comes a breaking point at which such efforts no longer make sense, and the transition to a new, more efficient clean energy grid becomes inevitable. As discussed below, a similar process is just beginning within the human energy sector, with substantial efforts being undertaken to make the current low-efficiency and environmentally problematic food production and distribution system slightly more efficient. However, as was the case with mechanical energy, the inevitable (and indeed more effective) way forward is to replace archaic and outdated food production methods with clean and efficient alternatives that do more than provide modest, incremental improvements to inherently dirty and inefficient food production technologies.

II. THE DIRTY AND INEFFICIENT HUMAN ENERGY GRID

There is no free lunch in the human food system. Every meal has a cost. Whether it is the use of finite resources such as topsoil, phosphorus, and fresh water, or the emission of greenhouse gases (GHGs), water pollution, or other air pollutants, every meal has a “foodprint.” Despite these costs, the twin yardsticks of clean energy—cleanliness and efficiency—are rarely applied to policy discussions concerning the food system. Instead, policymakers and scientists speak almost exclusively in terms of “sustainability.”³² But sustainability is a

have pledged to cut back or eliminate investments in coal”); *Staff Report to the Secretary on Electricity Markets and Reliability*, U.S. DEP’T ENERGY 21 (Aug. 2017), http://www.energy.gov/sites/prod/files/2017/08/f36/Staff%20Report%20on%20Electricity%20Markets%20and%20Reliability_0.pdf [<http://perma.cc/5AB4-QCBM>] (“Coal energy production peaked in 2007 and has been declining since. No new coal plants have been built for domestic utility electricity production since 2014 because new coal plants are more expensive to build and operate than natural gas-fired plants.”).

31. See Kurt Eichenwald, *Why Donald Trump Can’t Save the Coal Industry*, NEWSWEEK (Mar. 30, 2017), <http://www.newsweek.com/donald-trump-coal-clean-power-barack-obama-epa-energy-environment-solar-job-576458> [<http://perma.cc/BX68-RPAG>]; Jeff Goodell, *Scott Pruitt Can’t Stop the Death of Big Coal*, ROLLING STONE (Oct. 10, 2017), <http://www.rollingstone.com/politics/features/scott-pruitt-cant-stop-the-death-of-big-coal-w508077> [<http://perma.cc/CP2K-22TX>]; Dino Grandoni, *Trump Keeps Saying ‘Clean Coal.’ It Does Not Mean What He Thinks It Means*, WASH. POST (Aug. 23, 2017), <http://www.washingtonpost.com/news/energy-environment/wp/2017/08/23/trump-keeps-saying-clean-coal-it-does-not-mean-what-he-thinks-it-means/> [<http://perma.cc/X982-LPMU>].
32. See, e.g., ANNA ANDERSON, *WOMEN AND SUSTAINABLE AGRICULTURE: INTERVIEWS WITH 14 AGENTS OF CHANGE* (2004); ROGER LEAKEY, *MULTIFUNCTIONAL AGRICULTURE: ACHIEVING SUSTAINABLE DEVELOPMENT IN AFRICA* (2017); N.G. RÖLING & M.A.E. WAGEMAKERS, *FACILITATING SUSTAINABLE AGRICULTURE:*

concept without either clear definition or scientific foundation. The prevailing definition of sustainability—“the use of resources at rates that do not exceed the capacity of Earth to replace them”³³—does little or no work to meaningfully evaluate either the cleanliness or efficiency of the food production practice to which it is attached.³⁴ Rather, it is most commonly deployed as an advertising word, like “green,” “healthy,” or “fresh.”³⁵

Even Professor Jason Lusk, a staunch defender of the current industrial agricultural system, has bemoaned the emptiness of “sustainability” as a yardstick for judging the merits of existing and future food technologies and policy choices. As Lusk notes:

One of the problems with the concept of sustainability is that no one really knows what it means. . . . Depending on whom you ask, sustainability could mean everything from economic efficiency to environmental justice to organic, locally grown free-range chickens. And, of course, a lot of skeptics think that big business has co-opted and greenwashed the term. It’s now common for executive suites to house chief sustainability officers (CSOs) next to CEOs and CGOs.³⁶

Although there are some questionable assertions in Lusk’s provocative book *Unnaturally Delicious*,³⁷ Lusk is right on target in his criticism of sustainability. The academic and corporate food policy community’s persistent reliance on the meaningless platitude of sustainability rather than concrete assessments of relative efficiency and pollution is a serious problem. As discussed below, ap-

PARTICIPATORY LEARNING AND ADAPTIVE MANAGEMENT IN TIMES OF ENVIRONMENTAL UNCERTAINTY (1998); SUSAN SCHNEIDER, *FOOD, FARMING, AND SUSTAINABILITY* (2011); J.L. Buttriss, *Nine Billion Mouths to Feed by 2050: The Challenge of Establishing a Sustainable Food Supply*, 35 *NUTRITION FOUND. BULL.* 219 (2010).

33. See H. Charles J. Godfray et al., *Food Security: The Challenge of Feeding 9 Billion People*, 327 *SCI.* 812, 814 (2010).
34. *Id.* (“[W]e do not yet have good enough metrics of sustainability, a major problem when evaluating alternative strategies and negotiating trade-offs.”); see also Tara Garnett et al., *Lean, Green, Mean, Obscene . . . ? What is Efficiency and is it Sustainable?*, *FOOD CLIMATE RES. NETWORK* (2015), http://fcrn.org.uk/sites/default/files/fcrn_lmgo.pdf [<http://perma.cc/8LM8-VU9P>] (discussing the limits of both “efficiency” and “sustainability” in food policy).
35. A recent and entirely unscientific survey of a local grocery outlet by the author counted dozens of assertions of “sustainability” on a host of products without any explanation of what the term means or why it applies to a particular agricultural commodity.
36. See JASON LUSK, *UNNATURALLY DELICIOUS: HOW SCIENCE AND TECHNOLOGY ARE SERVING UP SUPER FOODS* 119 (2016).
37. Most notably his ten-page defense of what the author describes as both “pink slime” and its less well-known moniker “lean finely textured beef.” *Id.* at 149-59.

plying the framework of clean energy is a far more fruitful foundation for framing food-related policy discussions, meaningfully evaluating the food system, and exploring reforms.

But human energy production does not fare very well when examined under the microscope we apply to mechanical energy production. By any rational measure, the current human energy grid is extraordinarily dirty and inefficient. Despite the technological improvements and increases in overall agricultural outputs trumpeted by Lusk and others, the fundamental process of bringing calories from planting to consumption is so archaic that it would be entirely familiar to the citizen farmers who signed the Declaration of Independence in 1776. Indeed, as discussed below, internal combustion engines and coal-fired power plants look clean and efficient compared to the global food grid.

This is not to say that we should myopically focus on cleanliness and efficiency and overlook other critical issues associated with food policy. As food law scholars have noted, food policy discussions often fail to consider many other important concepts, including food justice, worker rights, gender equality, and other issues that are key to evaluating the environmental and social quality of the food system.³⁸ While some conventional conceptualizations of food cleanliness and efficiency can be somewhat objective—e.g., a measure of resource and energy inputs, associated conversion rates, and resulting pollution—the question of social cleanliness and efficiency is far more complex. As explained in a 2015 report from a coalition of food policy think tanks, *Cultivating Equality: Delivering Just and Sustainable Food Systems in a Changing Climate*:

If we are to achieve the new Sustainable Development Goal of ending hunger by 2030, we must address the underlying inequalities in food systems. In a changing climate, agriculture and food systems must be sustainable and productive—but our efforts cannot end there. They must be profitable for those for whom it is a livelihood; they must be equitable, to facilitate a level playing field in the market, to secure rights to resources for food producers, and to ensure access to nutritious food for all; they must be resilient to build the capacity of populations vulnerable to economic shocks, political instability, and increas-

38. See, e.g., Joseph Page, *Book Review: Food Law & Policy in the United States*, 72 *FOOD & DRUG L.J.* 361, 363 (2017) (noting that a broad understanding of food law and policy “includes, for example, issues relating to the ownership of agricultural property, the water rights needed to sustain agriculture, tax incentives to preserve family farms, agricultural research and education, governmental economic programs to prevent agricultural surplus and to stabilize agricultural prices, food distribution programs for schoolchildren and the poor, programs to provide nutrition education and to prevent obesity, and a host of other policies that impinge on food and agriculture.”) (quoting Peter Hutt, *Food Law & Policy: An Essay*, 1 *J. FOOD L. & POL’Y* 1, 2-3 (2005)).

ing, climate-induced natural hazards to recover and still lift themselves out of poverty.³⁹

As discussed below, I believe these elements of “new sustainability” can be incorporated into the concept of clean food, which should encompass both environmental *and social* costs. Some of the most serious of these costs are: (1) environmental pollution and resource depletion; (2) food loss from waste and inefficiency; and (3) the proliferation of global food insecurity. Even a cursory review of these three core problems highlights the staggering contradiction between how we conceptualize clean energy and clean food, and the pressing need for a shift in our thinking about human energy.

A. *The Environmental Cost of Agriculture*

The environmental and biodiversity cost of human food production is staggering, and raises questions about almost any deployment of the concept of “sustainable” in the same sentence with the word “agriculture.” As one group of food policy scholars has succinctly explained, “[b]y definition, dependency on nonrenewable inputs is unsustainable.”⁴⁰ But that is exactly what the global industrial agricultural system does in the modern world. Land, soil, water, energy, fertilizer, and other agricultural inputs—once thought to be infinite, renewable resources—are rapidly becoming scarce, dwindling commodities. The world treats food production much the way we treated petroleum fifty years ago, as we treated forests seventy-five years before that, and as we treated the great whale stocks of the world a century earlier: limitless resources for human exploitation that require neither conservation nor collective management. A full review of the environmental impact of agriculture is far beyond the scope of this Essay.⁴¹ However, a few key facts and figures are worth noting.

First, according to a 2017 United Nations report prepared pursuant to the United Nations Convention to Combat Desertification, “roughly half of the world’s surface area has been converted to land grazed by domesticated animals, cultivated crops, or production forests resulting in the loss of more than

39. See Tonya Rawe et al., *Cultivating Equality: Delivering Just and Sustainable Food Systems in a Changing Climate*, FOOD TANK & CARE USA (2015), <http://cgspace.cgiar.org/rest/bitstreams/60485/retrieve> [http://perma.cc/J92S-VZX8]; see also Guadalupe Luna, *The Dominion of Agricultural Sustainability: Invisible Farm Laborers*, 2014 WIS. L. REV. 265, 266 (“Notwithstanding their unique placement at the bottom of food production, farmworkers are systematically omitted from integrated food systems discussions and related scholarly inquiry.”). Considerations about the humane treatment of food animals also reside outside the common discourse of agricultural “sustainability.”).

40. See Godfray et al., *supra* note 33 at 814.

41. For an excellent collection of articles on the environmental impacts of agriculture, see MARY JANE ANGELO, JASON CZARNEZKI & WILLIAM EUBANKS, FOOD, AGRICULTURE, AND ENVIRONMENTAL LAW 113-28 (2013).

half of the world's forests," which "has led to devastating environmental impacts at local, national, and global levels."⁴² The report notes that agriculture is also "the most significant cause of current land conversion in the tropics, resulting in the loss of biodiversity and ecosystem services."⁴³ The loss of biodiversity from agriculture and other threats has also reduced global wildlife populations by almost forty percent since 1970.⁴⁴

In addition, and despite an impressive track record of increasing total outputs over the last fifty years, most scientists agree that the global agricultural system is operating on borrowed time. As the UN report notes:

The modern agricultural system has resulted in huge increases in productivity, holding off the risk of famine in many parts of the world but, at the same time, is based on monocultures, genetically modified crops, and the intensive use of fertilizers and pesticides that undermine long-term sustainability. Food production accounts for 70 per cent of all freshwater withdrawals and 80 per cent of deforestation, while soil, the basis for global food security, is being contaminated, degraded, and eroded in many areas, resulting in long-term declines in productivity.⁴⁵

Existing agricultural lands and soil are being rapidly degraded, with upwards of thirty percent of all agricultural lands now considered unusable for food production.⁴⁶ More than seventy-five billion tons of soil are lost each year

42. See Peter Alexander, et al., *Human Appropriation of Land for Food: The Role of Diets*, 41 GLOBAL ENVTL. CHANGE 88, 88 (2016) ("Human appropriation of land for food production has fundamentally altered the Earth system, with impact on water, social, air quality, and the climate system."); *Global Land Outlook*, UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION 126 (2017), http://www.unccd.int/sites/default/files/documents/2017-09/GLO_Full_Report_low_res.pdf [<http://perma.cc/LN2G-6JR4>] ("Agriculture is the single biggest land use covering more than one-third of the world's land surface, not including Greenland and Antarctica.") [hereinafter *Global Land Outlook*].

43. See *Global Land Outlook*, *supra* note 42, at 43 ("Although the net area devoted to agriculture continues to expand, this expansion masks the loss of land due to degradation and land abandonment that results from soil loss, erosion, nutrient depletion, and salinization.").

44. See *Living Planet Report 2014: Species and Spaces, People and Places*, WORLD WILDLIFE FUND 12 (2014), http://www.wwf.or.jp/activities/data/WWF_LPR_2014.pdf [<http://perma.cc/UN3F-XCT8>].

45. See *Global Land Outlook*, *supra* note 42, at 11 ("From 1998 to 2013, approximately 20 per cent of the Earth's vegetated land surface showed persistent declining trends in productivity, apparent in 20 per cent of cropland, 16 per cent of forest land, 19 per cent of grassland, and 27 per cent of rangeland.").

46. See David Pimentel & Michael Burgess, *Soil Erosion Threatens Food Production*, 3 AGRIC. 443, 448 (2013) ("[D]uring the last 40 years about 30% of the world's cropland has become unproductive and much of that has been abandoned for growing crops."); see also *The Nature of Development: Integrating Conservation and*

due to poor farming practices,⁴⁷ and once lost, it can take more than a thousand years to restore just a few centimeters.⁴⁸ These troubling statistics led one official with the United Nations Food and Agriculture Organization to declare in 2014 that, absent intervention, the existing food system could deplete *all* of the world's topsoil within sixty years.⁴⁹

The outlook for water use and pollution is even worse. The world agricultural system is entirely dependent upon increasingly scarce water resources. Total global demand for fresh water has tripled since 1950.⁵⁰ Five hundred million people currently live in water-scarce areas—a number that is projected to grow to three billion by 2025.⁵¹ In addition, “[s]ome of the most densely populated regions of the world, such as the Mediterranean, the Middle East, India, China and Pakistan are predicted to face severe water shortages in the coming decades.”⁵² Indeed, “[t]he severity of the water crisis has prompted the United Nations in concluding that it is water scarcity, not a lack of arable land, that will be the major constraint to increased food production over the next few decades.”⁵³

Development to Support Sustainable, Resilient Societies, INTERACTION (June 2011), <http://www.interaction.org/sites/default/files/InterAction%20Nature%20of%20Development%20Paper%20final.pdf> [<http://perma.cc/AY7F-AXKL>].

47. Pimentel & Burgess, *supra* note 46, at 447 (“Worldwide it is estimated that approximately 75 billion tons of fertile soil are lost from world agricultural systems each year.”).
48. See *Where Food Begins*, UNITED NATIONS FOOD & AGRIC. ORG. (2015), <http://www.fao.org/resources/infographics/infographics-details/en/c/285853> [<http://perma.cc/3TUB-AJU5>].
49. See Chris Arsenault, *Only 60 Years of Farming Left if Soil Degradation Continues*, SCI. AM. (Dec. 5, 2014), <http://www.scientificamerican.com/article/only-60-years-of-farming-left-if-soil-degradation-continues/> [<http://perma.cc/G6KW-RDTB>] (“[I]f current rates of degradation continue all of the world’s top soil could be gone within 60 years, a senior UN official said on Friday . . . [and] [u]nless new approaches are adopted, the global amount of arable and productive land per person in 2050 will be only a quarter of the level in 1960.”).
50. See Munir A. Hanjra & M. Ejaz Qureshi, *Global Water Crisis and Future Food Security in an Era of Climate Change*, 35 FOOD POL’Y 365, 366 (2010) (“Data on water supply and demand are startling: about 450 million people in 29 countries face severe water shortages; about 20% more water than is now available will be needed to feed the additional three billion people by 2025; as much as two-thirds of the world population could be water-stressed by 2025; aquifers, which supply one-third of the world’s population, are being pumped out faster than nature can replenish them.”).
51. *Id.*
52. *Id.*
53. *Id.* at 365-66 (citing *Human Development Report 2006—Beyond Scarcity: Power, Poverty and the Global Water Crisis*, UNITED NATIONS DEV. PROGRAMME (2006), <http://www.undp.org/content/dam/undp/library/corporate/HDR/2006%20Global>

Irrigated agriculture uses approximately eighty percent of the total global water supply.⁵⁴ But agriculture does not just use most of the world's fresh water, it is also a major source of water pollution and degradation of those waters. Approximately "half of the world's rivers and lakes are polluted; and major rivers, such as the Yellow, Ganges, and Colorado, do not flow to the sea for much of the year because of upstream withdrawal."⁵⁵ As explained in the 2017 United Nations report, "[m]odern methods of food production rely on the ability to add enough nutrients, mainly nitrate, phosphate, and potassium to the soil to boost plant growth and increase yields," but "the inefficiency in their application leads to major detriment in the wider environment, causing air and water pollution, ecosystem damage, and risks to human health."⁵⁶

The three largest agricultural pollution sources are leaching of pesticides, fertilizers, and nutrients into waterways; wastewater from food-processing facilities; and manure runoff and release from livestock facilities.⁵⁷ "Leaching from agricultural areas results in nitrate and phosphate polluting surface and groundwater supplies; excess nutrients promote rapid algal growth and, when the latter die, the loss of oxygen as plant matter decomposes."⁵⁸ This has led to large areas of eutrophication, like the infamous Gulf of Mexico Dead Zone, which cause "fish and other mobile organisms to leave due to the lack of oxygen," and other marine organisms to "die off and cause a food chain collapse."⁵⁹ "Reported cases of coastal dead zones have doubled in each of the last four decades, with over 500 currently known."⁶⁰

The major player in all of this agricultural water consumption and pollution is animal agriculture.⁶¹ Food and forage crops require approximately 300 to 2000 liters of water per kilogram of crop yield.⁶² In contrast, every kilogram of

<http://perma.cc/6MS5-KT9V>].

54. *Id.*

55. *Id.*

56. See *Global Land Outlook*, *supra* note 42, at 136.

57. See Jason Czarnezki & Elisa Prescott, *Environment and Climate Impacts of Food Production, Processing, Packaging, and Distribution*, in *FOOD, AGRICULTURE, AND ENVIRONMENTAL LAW* 113-28 (Mary Jane Angelo, Jason Czarnezki & William S. Eubanks II eds., 2013).

58. See *Global Land Outlook*, *supra* note 42.

59. William S. Eubanks II, *A Rotten System: Subsidizing Environmental Degradation and Poor Public Health with Our Nation's Tax Dollars*, 28 *STAN. ENVTL. L.J.* 213, 255-56 (2009).

60. *Global Land Outlook*, *supra* note 42, at 136.

61. Eubanks, *supra* note 59, at 259-61.

62. David Pimentel et al., *Water Resources: Agricultural and Environmental Issues*, 54 *BIOSCIENCE* 909, 911 (2004).

beef requires 43,000 liters of water—twenty-one times the water required for a kilogram of soybeans—one of the most water-intensive plant crops.⁶³ All told, livestock production “consumes on average 55 trillion gallons of water annually—more than 520 times the water used in hydraulic fracturing.”⁶⁴

The figures for water pollution from animal agriculture are similarly jarring. In the United States alone, livestock confinement facilities “generate about 500 million tons of manure annually.”⁶⁵ This is roughly three times the total amount of human waste generated annually by the U.S. population.⁶⁶ A single dairy farm with 2,500 animals can produce as much waste as a city of 400,000 people.⁶⁷

The waste from these facilities often contains a toxic mix of “hazardous pollutants, including antibiotics and hormones, biodegradable organics, heavy metals, nutrients, pathogens, pesticides, salts, sediments, and suspended solids.”⁶⁸ Most of this waste is stored in lagoons, spread on land, or injected underground.⁶⁹ All of these disposal methods are pathways for pollution of ground and surface waters.⁷⁰ Even a single spill can cause massive impacts. The

63. *Id.* This is true on a per-calorie basis as well. See Mesfin Mekonnen & Arjen Hoekstra, *A Global Assessment of the Water Footprint of Farm Animal Products*, 15 ECOSYSTEMS 401, 401 (2012) (“The average water footprint per calorie for beef is 20 times larger than for cereals and starchy roots.”).

64. Christopher Hyner, *A Leading Cause of Everything: One Industry That Is Destroying Our Planet and Our Ability To Thrive on It*, ENVTL. L. REV. SYNDICATE (2015), <http://gelr.org/2015/10/23/a-leading-cause-of-everything-one-industry-that-is-destroying-our-planet-and-our-ability-to-thrive-on-it-georgetown-environmental-law-review/> [<http://perma.cc/GGQ6-U53G>] (citing Office of Research & Dev., *Draft Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources* No. EPA/600/D-11/001, U.S. ENVTL. PROTECTION AGENCY 14 (2011), http://www.epa.gov/sites/production/files/documents/HFStudyPlanDraft_SAB_020711.pdf [<http://perma.cc/28DD-X359>]).

65. Hannah Conner, *The Industrialization of Animal Agriculture: Connecting a Model With Its Impact on the Environment*, in FOOD, AGRICULTURE, AND ENVIRONMENTAL LAW, *supra* note 41, at 65, 69 (quoting National Pollution Discharge Elimination System Permitting Regulations and Effluent Limitations Guidelines and Standards for Concentrated Animal Feeding Operations (CAFOs), 68 Fed. Reg. 7176, 7180 (Feb. 12, 2003)).

66. *Id.* at 69 (“[T]he U.S. Environmental Protection Agency (EPA) estimates that the U.S. population of roughly 285 million people produces only about 150 million tons (wet weight) of sanitary waste per year.”).

67. *Id.* at 74.

68. *Id.*; see also Eubanks, *supra* note 59, at 259-61.

69. Conner, *supra* note 65, at 70-72.

70. See J.B. Ruhl, *Farms, Their Environmental Harms, and Environmental Law*, 27 ECOLOGY L.Q. 263, 285-91 (2000) (cataloging all the pathways by which animal agriculture waste can pollute waterways).

most infamous example is the 1995 spill in North Carolina, which released “25 million gallons of hog waste—more than twice the volume of the Exxon Valdez oil spill” into a local river, and killed millions of fish and other aquatic animals.⁷¹

The world agriculture system also requires substantial energy inputs. The modern industrial farming system is highly dependent on petroleum products to power farm machinery, to manufacture fertilizers and pesticides, to process food, and to transport food commodities the long distances necessary to sustain a monoculture farming system.⁷² According to one estimate, it takes an average of “[ten] calories of petroleum to yield just one calorie of industrial food,” and “two-thirds of a gallon of gasoline to produce one bushel of corn.”⁷³ All told, the human food system eats up approximately thirty percent of the total world output of energy.⁷⁴

The byproducts of this huge energy input are air pollution and GHG emission outputs. According to a 2017 study of the GHG emissions attributable to different food commodities, “[t]he consumption of food contributes to a significant proportion of a person’s overall greenhouse gas impact, with agricultural production accounting for 19–29% of global anthropogenic greenhouse gas emissions.”⁷⁵ Here again, livestock production is the runaway winner. According to a 2016 analysis in the Proceedings of the National Academy of Sciences, “[t]he food system is responsible for more than a quarter of all greenhouse gas (GHG) emissions, of which up to 80% are associated with livestock production.”⁷⁶ A 2017 study called these figures into question, and concluded instead

71. Conner, *supra* note 65, at 73 (quoting Robert Innes, *The Economics of Livestock Waste and Its Regulations*, 82 AM. J. AGRIC. ECON. 97, 97 (2000)).

72. See Mary Jane Angelo, *Corn, Carbon, and Conservation: Rethinking U.S. Agricultural Policy in a Changing Global Environment*, 17 GEO. MASON L. REV. 593, 612 (2010) (“Many of the inputs relied on in industrial agriculture are derived from fossil fuels. Nitrogen fertilizers are derived from natural gas made from fossil fuels. Most synthetic pesticides are made from fossil fuels. Fossil fuels, especially diesel and gasoline, are used for heavy machinery including tractors and combines as well as for transportation of agricultural products to processing facilities and ultimately to retail grocery stores.”).

73. *Id.* (first quote quoting Eubanks, *supra* note 59, at 270).

74. Ralph Sims et al., “Energy-Smart” *Food for People and Climate*, UNITED NATIONS FOOD & AGRIC. ORG. 2 (2011), <http://www.fao.org/3/a-i2454e.pdf> [<http://perma.cc/L86T-NXQT>].

75. Stephen Clune, Enda Crossin & Karli Verghese, *Systematic Review of Greenhouse Gas Emissions for Different Fresh Food Categories*, 140 J. CLEANER PRODUCTION 766, 766 (2017).

76. Marco Springmann et al., *Analysis and Valuation of the Health and Climate Change Cobenefits of Dietary Change*, 113 PROC. NAT’L ACAD. SCI. 4146, 4146 (2016); see also Stefan Schwarzer, *Growing Greenhouse Emissions from Meat*, UNITED NATIONS ENVTL. PROGRAMME 4 (Oct. 2012), http://na.unep.net/geas/archive/pdfs/GEAS_Oct2012_meatproduction.pdf [<http://perma.cc/DY3B>].

that “existing bottom-up inventories of livestock methane emissions in the US . . . are too low,” and appear to be based on “outdated information used to develop these emissions factors.”⁷⁷ While livestock production is certainly the dominant cause of GHG emissions from the agricultural sector, many plant-based food commodities also have an extraordinarily high emissions footprint.⁷⁸ For example, certain rice production practices,⁷⁹ and even greenhouse-grown tomatoes and strawberries.⁸⁰ In short, every part of the food grid emits GHG emissions, whether it’s lamb or legumes. It is just a question of how much.

B. Food Inefficiency and Waste

Given the high costs and externalities associated with every calorie we eat, one might expect the process of food production and consumption to be fine-tuned for maximum efficiency. Far from it. According to most studies, the average loss of food from farm to table in the United States is forty percent.⁸¹ In other words, one of every three units of human energy we produce is never used to power a person. It either ends up as farm waste, is lost or spoiled in transportation and storage, or is simply thrown into the landfill by consumers and retailers.⁸²

Indeed, “[o]ne reason that the world faces such grave pressures on land resources [discussed above] is the startling inefficiencies in the way that we pro-

-H9WA] (“emissions from livestock constitute nearly 80 per cent of all agricultural emissions”).

77. See Julie Wolf, Ghassem R. Asrar & Tristram O. West, *Revised Methane Emissions Factors and Spatially Distributed Annual Carbon Fluxes for Global Livestock*, 12 CARBON BALANCE & MGMT. 1, 1 (2017).
78. See Clune, Crossin & Verghese, *supra* note 75.
79. See *The State of Food and Agriculture: Climate Change, Agriculture, and Food Security*, UNITED NATIONS FOOD & AGRIC. ORG. 38 (2016), <http://www.fao.org/3/a-i6030e.pdf> [<http://perma.cc/9WGP-ECCX>] (“Rice cultivation is the most important source of agricultural emissions in Eastern and Southeast Asia (at 26 percent) . . .”); Yam Kanta Gaihre, Reiner Wassmann & Gina Villegas-Pangga, *Impact of Elevated Temperatures on Greenhouse Gas Emissions in Rice Systems: Interaction with Straw Incorporation Studied in a Growth Chamber Experiment*, 373 PLANT & SOIL 857, 858 (2013).
80. See Clune, Crossin & Verghese, *supra* note 75, at 772 tbl. 5.
81. See *Global Land Outlook*, *supra* note 42, at 129; *Food Wastage Footprint: Impacts on Natural Resources*, UNITED NATIONS FOOD & AGRIC. ORG. (2013), <http://www.fao.org/docrep/018/i3347e/i3347e.pdf> [<http://perma.cc/8CY2-DCH3>].
82. *Food Wastage Footprint*, *supra* note 81, at 8-14; *Global Land Outlook*, *supra* note 42, at 150; see also Stephen D. Porter & David S. Reay, *Addressing Food Supply Chain and Consumption Inefficiencies: Potential for Climate Change Mitigation*, 16 REGIONAL ENVTL. CHANGE 2279 (2016).

duce and consume food.”⁸³ On a global level, the rate of waste is only slightly better than the U.S.—“one-third of all food produced is wasted: this is equivalent to 1.3 Gt of edible food every year, grown on 1.4 billion hectares of land (an area larger than China).”⁸⁴ If food waste were a country, it would be burning through “250 km³ of water and USD 750 billion (equivalent to the GDP of Switzerland),” have “a cumulative carbon footprint of 3.3 Gt of CO₂ equivalent per year,” and be “the third largest emitter after the United States and China.”⁸⁵

To make matters worse, these figures and virtually all studies, reports, and policy discussions concerning food waste only count *physical loss* as waste. Efficiency is not included. Thus, when food policymakers talk about the domestic food grid having a forty percent loss rate, they are typically not including any calculations concerning the relative efficiency of various food production and processing techniques. This omission is critically important because the use of highly inefficient, traditional food energy conversion systems is the number one source of caloric loss between farm and table—vastly outstripping losses from production, handling, transportation, storage, and consumer waste.

The number one source of loss, and the coal-fired power plants of the human food grid, are animal agriculture systems. According to a 2017 study of waste in the global food system, there are six key sources of caloric loss: (1) crop production; (2) livestock feeding; (3) transportation; (4) processing; (5) consumer waste; and (6) consumer over-consumption of calories.⁸⁶ After examining both direct loss and loss through various pre-consumer food processing methods, the study concluded that “the highest loss rate [of calories produced] for the stages considered occurs for livestock production, with losses of 81-94%.”⁸⁷

This massive leak in the human energy grid is caused by the unavoidable fact that livestock are a grossly inefficient technology for processing feed into

83. *Global Land Outlook*, *supra* note 42, at 128; *see also* Porter & Reay, *supra* note 82.

84. *Global Land Outlook*, *supra* note 42, at 128 (“Other studies have estimated even greater losses with up to half of all food produced being wasted.”) (citing *Global Food Waste: Waste Not, Want Not*, INST. OF MECHANICAL ENGINEERS 2 (2013), <http://www.imeche.org/docs/default-source/default-document-library/global-food---waste-not-want-not.pdf> [<http://perma.cc/9TVY-FCBD>]); J. Lundqvist, C. de Fraiture & D. Molden, *Saving Water: From Field to Fork—Curbing Losses and Wastage in the Food Chain*, INT’L WATER MGMT. INST. (Nov. 2008), http://www.siwi.org/wp-content/uploads/2015/09/PB_From_Filed_to_fork_2008.pdf [<http://perma.cc/7ML4-HYDH>].

85. *See Global Land Outlook*, *supra* note 42; *see also* DRAWDOWN: THE MOST COMPREHENSIVE PLAN EVER PROPOSED TO REVERSE GLOBAL WARMING (Paul Hawken ed., 2017) (ranking food waste reform as the third ranked pathway to GHG reductions, far ahead of solar energy, family planning, LED lighting, and dozens of other more commonly discussed climate reforms).

86. *See* Alexander et al., *supra* note 9.

87. *Id.* at 193.

meat for human consumption.⁸⁸ As explained in the 2017 United Nations report, “36 per cent of calories produced by the world’s crops are diverted for animal feed, with only 12 per cent of those feed calories ultimately contributing to the human diet as meat and other animal products.”⁸⁹ All told, the United Nations report concluded that “a third of the total food value of global crop production is lost by ‘processing’ it through inefficient livestock systems.”⁹⁰ The 2017 Alexander study put the total somewhat higher, concluding that “livestock production accounts for 40.4-60.8% of all losses from crop harvest to food consumption” worldwide.⁹¹

C. *Starving Peter to Feed Paul*

The revelation that so much of the world’s entire caloric production is being lost because of an archaic, grossly inefficient human energy grid, and that animal agriculture is causing two-thirds of that loss, appears at first glance like national news. A scandal of global proportions revealing that current world food insecurity and the purported need to produce two-thirds more calories by 2050 is, at bottom, nothing more than a matter of managing waste and inefficiency. Well, not exactly. There are a number of social and structural problems that also feed world hunger.

As a threshold matter, the vast waste and inefficiency inherent in the current food production system is hardly a new discovery. Almost fifty years ago, the so-called neo-Malthusians sounded the alarm bell about what they saw as the planet’s inability to feed a mushrooming population, and the inevitable mass-starvation and death that would result.⁹² In 1971, Frances Moore Lappé penned her best-selling opus, *Diet for a Small Planet*, which warned about the environmental impact of wasteful meat production practices and their connection with global hunger.⁹³ Lappé advocated for the adoption of a vegetarian diet

88. *Id.* at 194 (“1.06 Gt of feed from crops (plus 0.44 Gt of forage crops and 2.48 Gt of grass) are consumed by livestock to produce 0.24 Gt of animal products.”); *Global Land Outlook*, *supra* note 42, at 129.

89. *Global Land Outlook*, *supra* note 42, at 129.

90. *Id.*

91. Alexander et al., *supra* note 9, at 193 (“Only 19.2-31.9%—less than a third—of biomass harvested from crops or grass is finally consumed by humans”); see also Doug Boucher, *You Might Be Wasting Food, Even If You’re Not Throwing It Away*, UNION OF CONCERNED SCIENTISTS (Nov. 29, 2017), <http://blog.ucsusa.org/doug-boucher/ways-we-waste-food> [<http://perma.cc/B2Z8-4FA4>] (“[N]either overconsumption nor consumer waste are the largest way we waste the resources that can be used to produce food. That turns out to be livestock production.”).

92. See generally PAUL R. EHRLICH & ANNE EHRLICH, *THE POPULATION BOMB* (1968); DONELLA H. MEADOWS ET AL., *THE LIMITS TO GROWTH* (1972).

93. FRANCES MOORE LAPPÉ, *DIET FOR A SMALL PLANET* (1971).

for environmental reasons, and relied on neo-Malthusian concepts of population growth and scarcity to support her arguments.⁹⁴

According to doctrine, we were rescued from the terrible fate of responsible food conservation and increased vegetarianism by the green revolution in agriculture. Led by the technical prowess of the United States, we vastly expanded total agricultural outputs, and generated an abundance that could feed the world.⁹⁵ The green revolution, the story goes, disproved the naysayers' dire predictions of ecological collapse under the weight of four, five, or even six billion people, and set the table for the cheap and abundant food now available to many (but not all) of the countries of the world.⁹⁶

But the gospel of agricultural productivism⁹⁷—that increasing gross harvest tonnage will lift all boats out of hunger and ensure perpetual food security for everyone—turns out to be somewhat apocryphal. From a clean energy perspective, the problem with agricultural productivism is that high output is *not* a measure of efficiency. Rather, as anyone who has watched a drag race can tell you, maximum energy output is quite often grossly *inefficient*. Thus, the industrial food system's remarkable and undeniable achievement in doubling agricul-

94. See *id.* at 18 (“I was influenced by the emerging ecology movement and the ‘limits to growth’ consciousness. . . . Paul Ehrlich’s book *The Population Bomb* exploded during this same period, and books like *Famine 1975* appeared. Newspaper headlines were telling us (as they still are) that we had reached the limits of the earth’s ability to feed us all.”).

95. See Lusk, *supra* note 36, at 3–6; see also Paul Lewis, *The Green Revolution Bears Fruit*, N.Y. TIMES (June 2, 1985), <http://www.nytimes.com/1985/06/02/weekinreview/the-green-revolution-bears-fruit.html> [<http://perma.cc/SG8S-FSUN>].

96. See Lusk, *supra* note 36, at 4–5 (“How did we avert the mass starvation predicted by the leading intellectuals of the seventeenth and eighteenth century? . . . We tried new things. We tinkered. We invented. We made mistakes. And we tried again. The result is that we now get more than 500 percent more corn and 280 percent more wheat per acre of planted farmland than we did a century ago.”); see also Ronald Bailey, *Billions Served: Three Decades After He Launched the Green Revolution, Agronomist Norman Borlaug Is Still Fighting World Hunger—and the Doomayers Who Say It’s a Lost Cause*, 31 REASON 30 (2000).

97. See Olivier De Schutter, *The Specter of Productivism and Food Democracy*, 2014 WIS. L. REV. 199 (describing the shortcomings of total agricultural output as a measure of food security and the resulting failure of “productivism” to solve global hunger in the 21st century). For a critique of the concept of productivism in agricultural policy, see Nick Evans, Carol Morris & Michael Winter, *Conceptualizing Agriculture: A Critique of Post-Productivism as the New Orthodoxy*, 26 PROGRESS IN HUM. GEOGRAPHY 313 (2002) (questioning the value of a dualistic productivism versus post-productivism model in agricultural policy). See also Michael Roche & Neil Argent, *The Fall and Rise of Agricultural Productivism? An Antipodean Viewpoint*, 39 PROGRESS IN HUM. GEOGRAPHY 621, 622 (2015) (“We feel increasingly uneasy at the now frequent loose use of terms like monofunctionality, multifunctionality, hyperproductivism, super-productivism, and neoproductivism.”).

tural outputs in the last fifty years says nothing about the efficiency of the various agricultural practices within the agricultural system, or how to evaluate various food policy choices. Simply setting all the dials to maximum output, regardless of the environmental or social externalities, would never be accepted as a stand-in for cleanliness and efficiency in the mechanical energy grid, and it is not an acceptable measure of a clean human energy grid either.

The problem is that the high agricultural outputs associated with the green revolution have an equally high number of unresolved externalities—both environmental and social. As the 2017 United Nations report explains:

The “green revolution” in the 1970s promoted high-yielding varieties of crops, such as rice, which relied on increased inputs of mainly chemical fertilizers and pesticides. The result has been a much-needed boost in food production but also an accumulation of long-term problems with soil and human health, increases in crop pests and diseases, offsite pollution, and the loss of genetic diversity. At the same time, agriculture in parts of the world that have not adopted modern practices remains inefficient and can also inhibit the long-term sustainability of the food production system.⁹⁸

Indeed, the fruits of fifty years of productivism have left millions of people around the globe without basic food security, and created an international system of food oppression that prevents developing nations from achieving domestic food security.⁹⁹

As explained by Professor Olivier De Schutter—who served for many years as the United Nations Special Rapporteur on the Right to Food—“the food systems we inherited from the twentieth century have failed spectacularly.”¹⁰⁰ De Schutter and others have identified two major structural problems that the green revolution not only failed to resolve, but has actually exacerbated: “hidden hunger” and the lack of food security in developing nations.¹⁰¹ As explained in the 2017 United Nations report, “[t]he boost in production and profits has been matched by a steady build-up of side effects and a growing number of ‘have-nots’ who are neglected and continue to suffer malnutrition.”¹⁰²

Thus, “despite the impressive increase in agricultural output per capita, the number of hungry people has hardly been reduced throughout the period, and as a proportion of the total population, the hungry and the malnourished re-

98. *Global Land Outlook*, *supra* note 42, at 127.

99. See Andrea Freedman, *Fast Food: Oppression Through Poor Nutrition*, 95 CAL. L. REV. 2221, 2221-22 (2007) (describing in another context how “[f]ood oppression undermines both the survival and well-being of low income, urban communities of color” by “denying inner-city people of color access to healthy food.”).

100. See De Schutter, *supra* note 97, at 202.

101. *Id.* at 202-14.

102. *Global Land Outlook*, *supra* note 42, at 135.

main an unacceptably high contingent.”¹⁰³ De Schutter’s claims run counter to numerous assertions that the green revolution and new agricultural technology have significantly reduced worldwide hunger.¹⁰⁴ So, who is right? As with any debate, it depends on how you define terms.¹⁰⁵ The United Nations defines hunger as having “food energy availability [that] is inadequate to cover even minimum needs for a sedentary lifestyle.”¹⁰⁶ But defining hunger based on the energy needs for “a sedentary lifestyle” overlooks the fact that, unlike wealthy North Americans, “many of the poor perform physically demanding activities in difficult conditions.”¹⁰⁷ As Frances Moore Lappé explains,

While an assumption of calories needed for a “sedentary lifestyle” produces the publicized estimate of 868 million undernourished worldwide, the data in the online indicators show the consequence of assuming a caloric threshold required for “normal” activity. The rise is dramatic: the number of undernourished people in 2010-2012 could be as high as 1.33 billion—or 53 percent greater than the official 868 million estimate¹⁰⁸

The UN’s crabbed definition of hunger not only vastly underestimates actual world hunger, it also has significant outsized impacts on women and girls, who are often denied equal access to food in times of shortages or disasters, and thus dramatically overrepresented among the world’s hungry.¹⁰⁹ Even for those

103. See De Schutter, *supra* note 97, at 202 n.16 (“[A]lthough cross-temporal comparisons are difficult to make due to changes in methodology across the whole period, the absolute number of hungry people hardly declined over the past forty years.”) (citing *The State of Food Insecurity in the World: Eradicating World Hunger*, UNITED NATIONS FOOD & AGRIC. ORG. 8 (2006), <http://www.env-edu.gr/Documents/Food%20Insecurity%20in%20the%20World%20-%202006.pdf> [<http://perma.cc/N9S3-QVVG>]).

104. See, e.g., Lusk, *supra* note 36, at 3-4; see also De Schutter, *supra* note 97, at 203 (noting that the United Nations estimated in 2012 that worldwide hunger has “decreased globally from over 1 billion in 1990-92, representing 18.9 percent of the world’s population, to 842 million in 2011-13, or 12 percent of the population.”).

105. See *id.*; Frances Moore Lappé et al., *How We Count Hunger Matters*, 27 ETHICS & INT’L AFF. 251, 252-53 (2013).

106. See De Schutter, *supra* note 97, at 203 (quoting *The State of Food Security in the World: Economic Growth is Necessary but Not Sufficient to Accelerate Reduction of Hunger and Malnutrition*, UNITED NATIONS FOOD & AGRIC. ORG. 50 (2012), <http://www.fao.org/docrep/016/i3027e/i3027e.pdf> [<http://perma.cc/V7MW-QYXC>]); see also Lappé et al., *supra* note 105, at 252 (same).

107. De Schutter, *supra* note 97, at 203; see also Lappé et al., *supra* note 105, at 252-53.

108. Lappé et al., *supra* note 105, at 253.

109. De Schutter, *supra* note 97, at 203 (noting that the UN’s method of calculating hunger “neglect[s] inequalities in intra-household distribution of food, although

living in a country where industrial agriculture has allegedly provided “more than we can ever want,”¹¹⁰ the reports of the death of hunger have been greatly exaggerated. For example, “in the United States itself, 49 million Americans—one in six—live in ‘food insecure’ households, meaning they cannot afford adequate food for themselves or their families.”¹¹¹

There is no clear pathway out of perpetual food scarcity and hunger for many developing nations of the world. Many of these countries have ample land and resources to grow food for their own populations, but are focused instead on growing “cash crops that could earn hard currencies and thus allow the countries concerned to pay back their foreign debt.”¹¹² As De Schutter explains,

[T]he resources of developing countries are increasingly used to satisfy demand for raw commodities in rich countries. This pits the interests of consumers in countries with a vastly higher purchasing power against those of rural populations in the global South, which, except for a minority, shall not benefit from higher volumes of exports. The considerable amount of land going to grow soybeans, wheat, rye, oats, and maize to feed animals abroad illustrates this: the “soy empires” that are emerging in Brazil and Argentina, for instance, may represent a major source of export revenue for these countries, as they largely serve to feed animals in the European Union.¹¹³

These developing nations are, in essence, trapped in a neo-colonial system of food resource appropriation and exportation from poor nations to wealthy northern luxury economies.¹¹⁴ Thus, regardless of overall food production out-

it is well known that women and girls within households are the first ones to sacrifice themselves in times of crisis”); see also Fatima Denton, *Climate Change Vulnerability, Impacts, and Adaptation: Why Does Gender Matter?*, 10 GENDER & DEV. 10, 12 (2002); Jonathan Lovvorn, *Climate Change Beyond Environmentalism Part I: Intersectional Threats and the Case for Collective Action*, 29 GEO. ENVTL. L. REV. 1, 34-35 (2016).

110. Lusk, *supra* note 36, at 4.

111. De Schutter, *supra* note 97, at 204 (citing *Food Security in the U.S.*, U.S. DEP’T OF AGRIC. (2014), <http://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/key-statistics-graphics.aspx#foodsecure> [<http://perma.cc/4HWP-GKLB>]).

112. *Id.* at 218.

113. *Id.* at 219 & n.87 (“It has been calculated that, in order to feed animals in the EU, more than 16 million hectares of land were used to grow soybean outside the EU, a concept sometimes referred to ‘virtual trade in land.’”) (citing HEINRICH BÖLL STIFTUNG, FRIEND OF THE EARTH EUROPEAN MEAT ATLAS 30-31 (2014)).

114. *Id.* at 220-21 (“The reason that large areas of farmland can be dedicated to producing feedstock to satisfy the meat overconsumption in affluent societies or to fuel their cars, is because consumers in rich countries can command the resources that will allow their lifestyles to continue unchallenged.”).

puts, the root cause of world hunger cannot be meaningfully addressed in-country. Rather, “if the situation of hunger and malnutrition is to improve in the global South, it can only be through reforms in rich countries.”¹¹⁵

III. CLEAN FOOD

The waste, inefficiency, and inequity of this system of food oppression—coupled with the looming risks posed by climate change, erosion, nutrient loss, water shortages, and other factors—can appear overwhelming, an inherent side effect of global capitalism, free trade, and economic inequality that is beyond the ability of food policymakers or consumers to effectively tackle. I think not.

Applying the framework of clean energy to food can help solve many of these problems. What is the most clean and efficient method of human energy production in each community? How do we retire dirty and inefficient human energy technologies? What should we do to promote the development of clean human energy alternatives? None of these questions can be answered with the dogma of productivism, nor by jousting at the windmill of global capitalism.

My proposal here is as epistemologically simple as it is politically difficult. We need to discard meaningless measures of the human food grid like “sustainability” and how much gross production we can squeeze out of the land and water regardless of its social and biological externalities, and adopt the more measurable policy framework borrowed from the clean energy sector. If we can replace words like “sustainable” with standards like “clean and efficient,” we can move the ball a long way towards a more constructive discourse about food policy. By liberating food policy from its archaic assumptions and limited definitions of “waste,” we can not only have a more objective conversation about improving global food security, but also consider simple, cost-effective solutions to the need to ensure food security for ten billion people by 2050.

Based on the work done already by many others on various environmental and social costs concerning food, some rough matrices for evaluating clean food production systems can be constructed:

115. *Id.* at 221 (“[Developing countries will] continue to produce raw agricultural materials to satisfy our needs and import ever larger volumes of food produced in rich countries to feed themselves—thus making it impossible for their own food systems to be reshaped to meet their local demand and perpetuating their vulnerability to price shocks on international markets.”).

CLEAN FOOD

<u>CLEAN FOOD</u> ENVIRONMENTAL	
Water Inputs	What amount of freshwater is required per calorie produced in comparison to other food commodities?
Water Pollution	What pollutants, including toxics, antibiotics, and organic wastes are being released per calorie?
Air Pollutants (conventional)	What conventional air pollutants are being released per calorie, including during creation and transportation of material inputs, production and processing, and transportation of finished food?
Greenhouse Gasses	How much CO ₂ , methane, and other GHGs are being released per calorie, including during creation and transportation of material inputs, production and processing, and transportation of finished food?
Land Use	How many calories are being produced per acre of existing cropland, how much soil erosion, and how much new habitat is being cleared for production?

<u>CLEAN FOOD</u> EFFICIENCY	
Harvest Efficiency	How many calories are lost from harvest practices in comparison with other food commodities?
Processing Waste	How many calories are lost from mechanical processing and/or biological processing of calories through livestock?
Transportation Waste	How many calories are lost in transportation farm to table?
Consumer & Retail Waste	What is the rate of consumer and retail waste?

<u>CLEAN FOOD</u> SOCIAL	
Global Food Oppression	To what extent does a food commodity rely on material inputs imported from developing countries versus local resources in comparison to other food commodities, and does it contribute to global food security?
Food Justice	To what extent is it accessible to all socio-economic groups? For new technologies, is the technology portable to underserved communities and developing nations, or is it primarily a specialty item for wealthy consumers in technologically advanced countries?
Labor	To what extent does it rely on exploitive labor practices domestically or abroad in comparison to other food commodities?
Animal Welfare	To what extent does it rely on the inhumane treatment of animals in comparison to other food commodities?
Food Safety	What is the relative safety of the food commodity for consumers in comparison to other food commodities?
Additional Factors	Are there other environmental or social externalities that are not present with respect to other food commodities?

Using these matrices, the relative cleanliness and efficiency of various food items and food production methods can theoretically be compared and ranked by everyone from policymakers to consumers. To be sure, many of these factors have a considerable amount of subjectivity. This is inescapable, especially for issues related to the social cost of food. But it would be a worthwhile effort to conduct a methodical analysis of existing food staples and production methods under matrices. Those that rise to the top should be expanded and provided with new investment capital. Those at the bottom should begin the process of being phased out immediately.

Likewise, and perhaps more importantly, any new food production technology being brought online should also be evaluated under this framework to ensure it is not merely checking one box at the expense of another. A number of new ideas for changing food production have gained significant traction recently, both in food policy circles and in the popular press. Different innovators and investors have been working on everything from cricket farming to aquaculture

to creating meat without using any animals.¹¹⁶ All of these ideas are being promoted based on assertions that they are more “sustainable” alternatives to conventional food production, but to date very few of these claims have been rigorously tested.¹¹⁷ Food system disruptors, like all technological innovators, tend to focus on one aspect of a problem, or argue for the adoption of new technology because it can deliver the same product or service for less money than the least efficient existing food production systems—usually meat production.¹¹⁸ This is

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116. See *The State of the World's Fisheries and Aquaculture*, UNITED NATIONS FOOD AND AGRIC. ORG. (2016), <http://www.fao.org/3/a-i5555e.pdf> [<http://perma.cc/CQ3R-MTTW>] (predicting that aquaculture will rise dramatically in the near future and supply a greater portion of the world's fish proteins); Arnold Van Huis, *Potential of Insects as Food and Feed in Assuring Food Security*, 58 ANN. REV. ENTOMOLOGY 563 (2013); Chloe Cornish, *Silicon Valley Sets Sights on Disrupting Meat Industry*, FIN. TIMES (Nov. 12, 2017), <http://www.ft.com/content/c7795332-c666-11e7-a1d2-6786f39ef675> [<http://perma.cc/DG9N-F6J9>]; K. Lang et al., *Impact Investing in Sustainable Food and Agriculture Across Asset Classes*, TRILLIUM ASSET MGMT. (May 2017), <http://www.trilliuminvest.com/wp-content/uploads/2017/05/Investing-in-Sustainable-Food-and-Agriculture.pdf> [<http://perma.cc/CY2D-2657>]; Adele Peters, *This Giant Automated Cricket Farm is Designed to Make Bugs a Mainstream Source of Protein*, FAST CO. (Aug. 21, 2017), <http://www.fastcompany.com/40454212/this-automated-cricket-farm-is-designed-to-make-bugs-a-mainstream-source-of-protein> [<http://perma.cc/6SK3-KGRC>]; Deena Shanker, *How We'll Eat Fish in the Future*, BLOOMBERG (May 26, 2017), <http://www.bloomberg.com/news/articles/2017-05-26/the-future-of-fish-investors-get-into-sustainable-aquaculture> [<http://perma.cc/T6S9-HTC6>].
117. For an excellent analysis of the land use efficiency of insect farming, cultured meat, and other alternative protein sources, see Peter Alexander et al., *Could Consumption of Insects, Cultured Meat or Imitation Meat Reduce Global Agricultural Land Use?*, 15 GLOBAL FOOD SECURITY 22 (2017).
118. See, e.g., *Silicon Valley Gets a Taste for Food: Tech Startups Are Moving Into the Food Business to Make Sustainable Versions of Meat and Dairy Products from Plants*, ECONOMIST (Mar. 5, 2015), <http://www.economist.com/news/technology-quarterly/21645497-tech-startups-are-moving-food-business-make-sustainable-versions-meat> [<http://perma.cc/6MMA-4K4N>]; Jon Card, *Lab-Grown Food, the Goal Is to Remove the Animal from Meat Production*, GUARDIAN (July 24, 2017), <http://www.theguardian.com/small-business-network/2017/jul/24/lab-grown-food-indiebio-artificial-intelligence-walmart-vegetarian> [<http://perma.cc/R8XX-2E44>]; Leanna Garfield, *Hampton Creek Says It's Making Lab-Grown Meat That Will Be in the Supermarkets by 2018*, BUS. INSIDER (June 27, 2017), <http://www.businessinsider.com/hampton-creek-lab-grown-meat-2017-6> [<http://perma.cc/JBB3-M63G>]; see also Hanna L. Tuomisto & M. Joost Teixeira de Mattos, *Environmental Impacts of Cultured Meat Production*, 45 ENVTL. SCI. TECH. 6117 (2011) (concluding that cultured meat is a more environmentally friendly and more efficient source of protein, but reaching this conclusion by comparing cultured meat production to “conventional livestock” and salmon—two of the least efficient, most wasteful, most GHG-intensive forms of protein production currently in use).

categorically *not* enough when it comes to clean food. Any new food technology should meet or exceed the cleanliness and efficiency of the most efficient existing methods of food production in order to be considered clean food. Otherwise, we are just swapping in high-tech low-efficiency food for low-tech low-efficiency food.¹¹⁹

Finally, and demonstrably, there are a whole host of unresolved questions associated with the clean food concept framed above. A few key issues merit discussion here. First, the various factors to consider on the clean food matrices can and will inevitably come into conflict with each other. What is best for efficiency might be problematic for land use. Promoting food security in developing countries might drive up the cost of food for underserved communities in developed nations. Any number of potential conflicts can arise. But this is by no means an argument against measuring food by the clean and efficient standard. Such questions are all too familiar to clean energy advocates, who have had to grapple with a number of similar conflicts, including between the benefits of natural gas (less CO₂ than coal), and its drawbacks (increased methane leakage). The existence of such problems does not mean we are not asking the right questions. Is this method of mechanical or human energy clean and efficient? What are the trade-offs between efficiency and cleanliness? Are we maximizing outputs while minimizing externalities—both environmental and social? The purpose of the proposed clean food matrices is to provide syntax and a better framework of questions, and not to provide all of the answers, or resolve inevitable policy conflicts in evaluating the cleanest and most efficient sources of human energy.

Second, there is something inherently troubling for many people about any proposal to disambiguate food efficiency from the prevailing focus on food culture and epicurean enjoyment. Rebranding food as “human energy” could be misconstrued as an argument for imposing some bleak form of food socialism—condemning everyone to a steady diet of lab-grown gruel three meals a day, seven days a week. But such an extreme outcome seems entirely far-fetched. The clean energy revolution may have helped move 1970s-era gas-guzzlers out of the mainstream commuting lanes, but it certainly did not end

119. A brief note about calories. Measuring agricultural outputs and efficiency is typically done by looking at total calories produced. But the prevailing food security framework of equating the delivery of sufficient calories with providing sufficient nutrition has come under fire in recent years. See De Schutter, *supra* note 97, at 204 (“Calorie intake alone, moreover, which is the sole indicator for undernutrition in the official data on hunger, says little about nutritional status,” but “inadequate diets can result in micronutrient deficiencies such as a lack of iodine, of vitamin A, or of iron, to mention only the deficiencies that are the most common in large parts of the developing world.”). Thus, it is important to analyze clean food efficiency by the twin yardsticks of total caloric production and waste, as well as the total nutritional value of differing food production technologies.

classic car collecting, NASCAR, or any number of small-scale, inefficient recreational uses of petroleum. Likewise, resetting our human energy framework to promote clean food does not mean the end of any particular food item, nor will it shutter the restaurant industry. Surely there must be some sweet spot of food policy between the false dichotomy of either (1) continuing blindly with the current food system, where grossly inefficient and dirty food items are thoughtlessly consumed based entirely on taste, price, and convenience; and (2) imposing a command and control utilitarian clean human energy regime bereft of culture, choice, and enjoyment. The world's various food cultures are strong enough to survive the addition of some basic level of rationality concerning the environmental and social cost of consumption.

Third, and relatedly, the long shadow of meat production and consumption inevitably hangs over this entire discussion. Numerous studies, reports, and popular articles are now pulling back the curtain on animal agriculture's role as a top-tier source of pollution and the largest source of waste in the human food grid.¹²⁰ The longstanding unspoken taboo in academic, political, and social circles against talking openly about the pollution and waste associated with animal agriculture is rapidly dissipating. At the same time, many of the popular press and policy discussions about animal agriculture can over-simplify and polarize the problem in a way that can inhibit discourse and progress.

The relative efficiency of any human food production system differs dramatically depending on the location, climate, topography, soils, natural vegetation, and available technology and infrastructure.¹²¹ While the raising of animals

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120. See *supra* notes 40-80 and accompanying text; see also Alexander et al., *supra* note 9, at 193 (“[L]ivestock production accounts for 40.4-60.8% of all losses from crop harvest to food consumption”); *Farms a Major Source of Air Pollution, Study Says*, AM. GEOPHYSICAL UNION (May 16, 2016), <http://news.agu.org/press-release/farms-a-major-source-of-air-pollution-study-finds/> [<http://perma.cc/QHW2-5Y2Y>] (“Emissions from farms outweigh all other human sources of fine-particulate air pollution in much of the United States, Europe, Russia and China, according to new research.”) (citing Susanne E. Bauer, Kostas Tsigaridis & Ron Miller, *Significant Atmospheric Aerosol Pollution Caused by World Food Cultivation*, 43 GEOPHYSICAL RES. LETTERS 5394 (2016)).
121. See, e.g., *The State of Food and Agriculture: Livestock in the Balance*, UNITED NATIONS FOOD & AGRIC. ORG. (2009), <http://www.fao.org/docrep/012/i0680e/i0680e.pdf> [<http://perma.cc/36RA-WKRH>] (describing the different animal agriculture systems around the world, identifying “grazing systems,” “mixed-farming systems,” and “industrial systems,” each suited to different natural environments and locations); Anne Mottet et al., *Livestock: On Our Plates or Eating at Our Table? A New Analysis of the Feed/Food Debate*, 14 GLOBAL FOOD SECURITY 1, 1 (2017) (“[W]hile some of the global discussion on food security may address the question of the feed/food competition, it often fails to mention the diversity of animal diets around the world and the various levels of efficiency in production systems.”).

for food might be the most dirty and inefficient method of food production in one location, as discussed above, the production of rice or strawberries might be the least efficient crop in another. Critics of animal agriculture can sometimes overlook this fact, and fall into the trap of absolutism concerning livestock production. At the same time, defenders of the animal agriculture industry have similarly resorted to extreme arguments, as evidenced by a 2017 study advancing the hypothetical claim that the sudden and total removal of every single livestock animal in the United States would lead to mass-starvation and nutritional deficiencies.¹²² The problems with this study are far too numerous to engage in this Essay, most notably the assumption that after removing billions of food animals, people would have to eat the massive amount of corn and soy currently grown as animal feed (and suffer adverse nutritional effects), rather than planting and harvesting crops that would support a well-rounded plant-based diet. It is enough to say that such extreme, hypothetical, and outright absurd assertions do little to advance discussions of food efficiency, security, or equity, and highlight the need to evaluate concrete, site-specific human energy production technologies under the same rubric as mechanical energy.¹²³ Rather than getting entangled in an absolutist debate about the merits of a meat versus meatless society, the clean food matrices provide a way forward that is not only more rational, but also firmly grounded in the successful framework of clean energy policy.

If society were to shift to a clean food model, how exactly would such a system be implemented? The answer is that it will be difficult, especially when the factors listed in the matrices come into conflict. But this does not mean it is not worth doing. The purpose of this Essay is to offer a new framework for discuss-

122. See Robin R. White & Mary Beth Hall, *Nutritional and Greenhouse Gas Impacts of Removing Animals from US Agriculture*, 114 PROC. NAT'L ACAD. SCI. 10301, 10301 (2017) ("This assessment suggests that removing animals from US agriculture would reduce agricultural GHG emissions, but would also create a food supply incapable of supporting the US population's nutritional requirements.").

123. Another common absolutist refrain leveled any time anyone asks questions about inefficiency and waste in the animal agriculture sector is that a large portion of the crops harvested world-wide is not edible by humans, and thus there is little to gain in rethinking the current use of livestock for food. See Mottet et al., *supra* note 121, at 7 ("86% [of crop yields consumed by livestock] is made of materials that are currently not eaten by humans"). Here again, this is a sweeping generalization based on the assumption that, even if we stopped feeding feed crops to livestock in a particular area, farmers would continue to grow useless animal feed crops, rather than planting crops that humans might actually buy and consume. This is not to say that the question of edible versus inedible crop inputs and conversion is not relevant to the clean food matrices. It is. But it needs to be evaluated holistically, not as an abstract declaration based on questionable assumptions about the entire plant-based food system remaining static, even if we adjust the number or type of livestock grown at a particular location.

ing food policy, and not to prejudge the analysis of specific food technologies without adequate scientific data and expertise. Detailed Life-Cycle Analyses (“LCAs”) will need to be consulted (or in some cases created) to assess the environmental factors reflected in the matrices. For the efficiency and social factors, engineering, economic, and social data will need to be collected and analyzed. Nevertheless, as is apparent from the foregoing discussion, some inherently dirty and inefficient food production systems—like industrial animal agriculture—are unlikely to score highly on any of the environmental, efficiency, and social matrix factors, and should therefore be prioritized for review. Likewise, given the amount of venture capital and technological effort being devoted to the development of alternative protein sources like cultured meat production, determining whether some of these emerging systems are merely trading in high-tech low-efficiency food for low-tech low-efficiency food should also be a priority for review, so that capital can be redistributed according to the results.

As is the case with mechanical energy, disclosure, transparency, and education are key to the entire process. When is the last time someone went to the grocery store looking for an “energy-efficient tomato,” or did a Google search for “eco-friendly brunch options”? Part of why we do not think of food in these terms is because, unlike automobiles, lightbulbs, refrigerators, and virtually every other mechanical energy driven device in our lives, there is no publicly available information or disclosure about the energy costs associated with food. Restaurants and grocery stores do not provide EPA Energy Star ratings on food items. So how can we improve this structural lack of consumer knowledge concerning the relative costs of different forms of human energy? One idea might be found in the example set by the Corporate Average Fuel Economy standards first issued in 1975, which transformed how automobiles were manufactured, marketed, and purchased.¹²⁴ A modest first step might be to develop a similar set of “CAFE” standards (pun intended) for clean food. Such standards would most likely need to initially be developed at the state or local level in light of Congress’ current disposition towards legislating food policy. This certainly would not be transformative of the human energy grid in and of itself.¹²⁵ But such standards could be an effective first step to developing a more robust dialogue about clean food, and ultimately precipitating a much-needed clean human energy revolution.

124. See Robert Crandall, *Policy Watch: Corporate Average Fuel Economy Standards*, bn 6 J. ECON. PERSPECTIVES 171 (1992); *Corporate Average Fuel Economy Standards/Greenhouse Gas Standards*, HARV. ENVTL. L. PROGRAM (2018), <http://environment.law.harvard.edu/2017/09/corporate-average-fuel-economy-standards> [<http://perma.cc/H5LP-4VDQ>].

125. The inconsistency of proposing as a first step towards clean food the promulgation of the very same “incremental steps” towards clean energy criticized above will not be lost on the careful reader. However, as was the case with the evolution of clean energy, progress on building a clean food future has to start somewhere.

CONCLUSION

Every living organism must consume energy of some type, and consumable energy is a finite resource. As we look for solutions to “power” the hundreds of millions of people who currently lack food security, and the billions more coming by 2050, we can improve our policy discourse by jettisoning unhelpful concepts like sustainability, avoiding reliance on the fiction of trickle-down productivism, and retiring existing taboos against talking honestly about the dirty and inefficient reality of livestock production. Advocates and policymakers pursuing a clean energy agenda should also rethink the role of food in the world energy grid, and adopt a holistic clean energy policy that includes clean food. Human energy is no different than mechanical energy, and building a clean food grid should be the next clean energy revolution.