# POSITIVE-SUM WATER-ENERGY-FOOD NEXUS GOVERNANCE

TROY RULE[*]

ABSTRACT

*This Article introduces the distinction between zero-sum and positive-sum water-energy-food (WEF) nexus interactions and argues for a greater policy focus on promoting interactions that are positive-sum. Historically, most WEF nexus governance research has centered on promoting more integrated management of scarcity-driven tradeoffs among nexus resources. Such research generally presumes that increasing the security of any one nexus resource necessarily diminishes the security of at least one of the others. In contrast, a small but growing subset of the WEF nexus governance literature focuses on what this Article calls "positive-sum" nexus interactions—synergistic nexus resource relationships unleashed by innovation and targeted capital investment. Unlike zero-sum nexus interactions, positive-sum interactions increase the security of at least one nexus resource while maintaining or improving the security of the other nexus resources. Although effectively managing zero-sum nexus resource interactions is an important part of WEF nexus governance, a greater emphasis on policy strategies that leverage positive-sum nexus resource interactions could ultimately spare communities and nations from facing as many resource tradeoffs in the coming decades. This Article outlines core differences between zero-sum and positive-sum WEF nexus resource interactions and argues that much more policy attention on positive-sum nexus strategies will be needed to build low-carbon, sustainable water, food, and energy systems across the world.*

ABSTRACT ........................................................................................117
INTRODUCTION ................................................................................119
I. THE WEF NEXUS FRAMEWORK AND ITS SHORTCOMINGS ........................120
A. A Selected Set of Externality Problems? ...................................121
B. Inconsistencies as the Nexus Construct Evolves ........................123
C. Untapped Potential .....................................................................125

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II. ZERO-SUM VERSUS POSITIVE-SUM NEXUS INTERACTIONS ....................126
A. WEF Nexus Interactions as a Zero-Sum Game ..........................126
1. Inflexible Resource Tradeoffs ............................................127
Figure A: .........................................................................128
Effect of a New Ethanol Fuel Requirement on a Region's Food-Energy Nexus Tradeoff Frontier.............................................128
Figure B: .........................................................................130
Effect of a New Ethanol Requirement on a Region's .....................130
Water-Energy-Food Nexus Tradeoff Frontier.................................130
2. Common Zero-Sum Nexus Conflicts and Their Governance Challenges .........................................................................130
B. Positive-Sum Nexus Interactions ...............................................134
1. Synergistic Relationships and Expandable Tradeoff Frontiers ..............................................................................134
Figure C: .........................................................................135
Effect of an Agrivoltaics Subsidy Program on a Region's..............135
Food-Energy Nexus Tradeoff Frontier ...........................................135
Figure D: .........................................................................136
Effect of an Agrivoltaics Subsidy Program on a Region's Water-Energy-Food Tradeoff Frontier ..............................................136
2. Historical Examples of Positive-Sum Nexus Moves...........136
C. Emerging Positive-Sum Nexus Strategies .................................139
1. Leveraging Solar Photovoltaic Technologies......................139
2. Leveraging Energy Storage Technologies...........................143
3. Other Potential Positive-Sum Strategies..............................144
III. POSITIVE-SUM NEXUS GOVERNANCE.............................................145
A. Policy Strategies for Expanding Nexus Tradeoff Frontiers........145
1. Reducing Policy Support for Zero-Sum Nexus Interactions ..............................................................................146
2. Taxing Zero-Sum Nexus Strategies....................................147
3. Promoting Private Investment in Positive-Sum Nexus Strategies ............................................................................148
B. Pitfalls to Avoid .........................................................................149
1. Triggering Overexploitation of an Open-Access Nexus Resource ............................................................................149
2. Ignoring Impacts on Non-Nexus Resources and Policy Priorities .............................................................................151
CONCLUSION ...................................................................................153

## INTRODUCTION

The water-energy-food (WEF) nexus is an increasingly popular framework for analyzing policy tradeoffs involving three of the world's most critical natural resources. The WEF nexus literature highlights how "institutional silos" and under-coordinated regimes for promoting water, energy, and food security can hamper broader progress toward sustainable development goals and advocates for more integrated management of nexus resources.[1]

The WEF nexus construct rests in part on an assumption of scarcity—a belief that, because nexus resources are finite and inextricably linked, increasing supplies of one of them tends to diminish capacity to supply one or more of the others.[2] Such scarcity and competition among resource types is unquestionably observable across the globe today as humankind struggles to provide enough clean water, safe food, and affordable energy for a growing global population on a rapidly warming planet. For instance, increasing food production typically necessitates additional energy generation, which often requires freshwater resources and thus leaves less water available for food production, and so on. WEF nexus governance research seeks out innovative strategies for managing these complex tradeoffs.

However, one drawback of the WEF nexus governance literature's fixation on scarcity and tradeoffs is that it can obscure a growing array of potentially synergistic interactions among nexus resources. It is increasingly possible for policymakers to flip the WEF nexus's scarcity paradigm on its head and advance water, energy, or food security while maintaining or expanding progress on the other two. Recent technological innovations have made such synergistic resource management strategies more feasible now than ever before, and inventive policymaking has a vital role to play in accelerating the deployment of these strategies across the globe.

Recognizing the distinct features and benefits of synergistic nexus resource interactions is a first step toward integrating them

[1] *See, e.g.*, Antti Belinskij, *Water-Energy-Food Nexus Within the Framework of International Water Law*, 7 WATER 5396, 5397 (2015).

[2] *See, e.g.*, Debra Perrone & George Hornberger, *Frontiers of the Food-Energy-Water Trilemma: Sri Lanka as a Microcosm of Tradeoffs*, 11 ENV'T RSCH. LETTERS 1, 1 (2016) (arguing that "interrelationships among food, energy, and water" are so intertwined that "a solution to address scarcity in one resource cannot be achieved without impact on the others").

into WEF nexus governance. Today's predominantly "zero-sum" view of nexus resource security relationships overlooks opportunities to build policies that harness "positive-sum'" nexus resource interactions. Strengthening efforts aimed at finding and exploiting these positive-sum interactions could ultimately spare communities and nations from facing as many zero-sum nexus tradeoffs in future decades.

This Article uses simple diagrams and real-world examples to highlight the important distinction between zero-sum and positive-sum WEF nexus interactions and argues that a greater policy focus on promoting positive-sum interactions will be needed to build sustainable water, food, and energy systems across the world. Part I of this Article provides a brief background on WEF nexus governance, its origins, and some of its core limitations. Part II outlines the basic differences between zero-sum and positive-sum nexus relationships and provides several examples of each. Part III then describes specific policy strategies capable of better driving private investment toward positive-sum WEF nexus resource interactions.

## I. The WEF Nexus Framework and Its Shortcomings

The WEF nexus is a relatively novel environmental policy construct. The nexus first drew significant attention in 2011 after the World Economic Forum published a book bearing the term in its title.[3] Produced within the Forum's Water Initiative, the book primarily employed the WEF nexus concept to underscore the essential role of freshwater supplies in maintaining global food and energy security.[4] Nearly a decade later, the WEF nexus is still

[3] *See* WORLD ECON. F. WATER INITIATIVE, WATER SECURITY: THE WATER-FOOD-ENERGY-CLIMATE NEXUS (Dominic Waughray ed., 2011).

[4] *See id.* at 3 ("Water . . . lies at the heart of a nexus of social, economic, and political issues—agriculture, energy, cities, trade, finance, national security, and human livelihoods, within rich and poor countries alike."). Indeed, some have suggested that the WEF's initial efforts to promote the nexus were deliberately designed to spur greater interest in protecting water security. *See* Rob C. de Loë & James J. Patterson, *Rethinking Water Governance: Moving Beyond Water-Centric Perspectives in a Connected and Changing World*, 57 NAT. RES. J. 75, 89 (2017) (citing Mike Muller, *The 'Nexus' as a Step Back Towards a More Coherent Water Resource Management Paradigm*, 8 WATER ALTS. 675 (2015)) ("[T]he water-energy-food nexus can be seen as a response to the perceived failure of

struggling to gain a foothold outside water policy circles.[5] Still, the framework embodies an ever more urgent need for greater focus on the difficult tradeoffs plaguing some of the planet's most essential resources.

On the surface, the basic message of the WEF nexus is clear: water, energy, and food security are all interconnected such that policy actions affecting any one of these three tend to materially impact at least one of the other three. However, beyond that general message there remains a lack of consensus regarding what the WEF nexus is or how it should inform resource governance. The following subsections constructively critique the WEF nexus construct and highlight some of its imperfections as a resource management tool.

### A. A Selected Set of Externality Problems?

In one sense, the WEF nexus is merely a novel way of framing age-old externality problems involving three environmental policy priorities. The nexus's fusion of water, energy, and food security into a single analytic framework is intuitive given that all three are essential to humankind's survival and that activities involving each are deeply interconnected. By spotlighting the complex interrelationships among these crucial resources in a unifying construct, the WEF nexus hopefully inspires some policymakers and private actors to more consciously manage this important web of interactions.

As enlightening as the WEF nexus can be, one possible downside of its exclusive focus on only three particular policy goals is its potential to obfuscate externality problems involving *other* global environmental policy objectives. It is not entirely clear why water, energy, and food security warrant inclusion within the nexus construct while multiple other vital environmental policy aims—many of which are included in the U.N. Sustainable Development Goals (SDGs)—fail to make the cut.[6] Land management is one

[integrated water resource management], specifically the lack of emphasis on 'what water may do for society rather than what society should do for water.'").

5 *See* Loë & Patterson, *supra* note 4, at 90 (noting that "the extent to which the water-energy-food nexus has moved beyond a project of the water community is being questioned").

6 Water security (Goal 6), energy security (Goal 7), and food security (Goal 15) are all included in the SDGs, but so are numerous other important environmental policy objectives that are absent within the WEF nexus framework.

example of a crucial activity that could have arguably fit within the WEF nexus structure but is typically omitted.[7] Land resources are unquestionably scarce and critically important to human survival. Likewise, land uses routinely affect water, energy, and food supplies and vice-versa.[8] Despite such significant interrelationships, land resource impacts are largely ignored in many versions of the WEF nexus.[9] This omission could lead some academicians and policymakers employing the nexus framework to under-consider land impacts when confronting nexus resource issues. Wildlife conservation, decarbonization, and efforts to ensure clean air and sanitary living conditions for all are other examples of activities that are profoundly interconnected with water, energy, and food security yet risk being marginalized due to their outsider status in the WEF nexus structure.[10]

For a recent comparison of the WEF nexus construct to the SDGs, *see generally* Waseem Ahmad Qureshi, *An Evaluation of the Water-Energy-Food Nexus and Its Alignment with the Sustainable Development Goals*, 9 PENN. ST. J.L. & INT'L AFFS. 58 (2021).

[7] There is at least one iteration of the nexus that treats land as a nexus "arm." *See generally* Claudia Ringler et al., *The Nexus Across Water, Energy, Land and Food (WELF): Potential for Improved Resource Use Efficiency?*, 5 CURRENT OP. ENV'T SUSTAINABILITY 617 (2013).

[8] For instance, renewable energy development plans in locales where land is scarce, such as Hawaii and Taiwan, have sparked vigorous opposition in recent years. *See, e.g.*, Stewart Yerton, *Residents and Policymakers Battle Over Hawaii Wind Energy Projects*, CIV. BEAT (Mar. 29, 2020), https://www.civilbeat.org/2020/03/residents-and-policymakers-battle-over-hawaii-wind-energy-projects; *see also* Angelica Oung, *New Solar Farm Rules Trigger Debate*, TAIPEI TIMES (July 14, 2020), https://www.taipeitimes.com/News/biz/archives/2020/07/14/2003739852.

[9] Other commentators have emphasized the crucially important role of land resources in WEF nexus resource interactions. *See, e.g.*, Tech. Support Team, U.N. Dep't of Econ. & Soc. Affs. & U.N. Dev. Programme, TST Issues Brief: Desertification, Land Degradation & Drought, https://sustainabledevelopment.un.org/content/documents/1803tstissuesdldd.pdf (last visited Mar. 3, 2023); *see also* Shelley Welton, Michela Biasutti & Michael Gerrard, *Legal & Scientific Integrity in Advancing a "Land Degradation Neutral World"*, 40 COLUM. J. ENV'T L. 39, 49 (2015) (examining the significant impacts of water, energy, and food production on land resources and highlighting the outsized role of land in maintaining sustainable water, energy, and food systems).

[10] For a detailed examination of biodiversity's interrelationship with renewable energy and other activities related to the WEF nexus, *see generally* RENEWABLE ENERGY AND WILDLIFE CONSERVATION (Christopher E. Moorman, Steven M. Grodsky & Susan P. Rupp eds., 2019).

### B. Inconsistencies as the Nexus Construct Evolves

Because the WEF nexus is still an evolving concept, disagreement regarding its scope and structure has also been a lingering challenge. For instance, there has been inconsistency over the years regarding whether water security occupies a uniquely elevated role within the WEF nexus construct. At least one early version of the WEF nexus placed "available water resources" in the center of a nexus diagram with food, energy, and "water supply security" arranged as three nexus "arms" emanating from it.[11] Within that early, water-centric version of the WEF nexus, water was the mother resource and food, energy, and drinking water were mere appendages.[12] More recently, however, most graphic portrayals of the WEF nexus present it as a balanced three-arm framework in which water, food, and energy systems hold equal importance and relevance—a more egalitarian approach that may be partly aimed at helping the model gain wider acceptance.[13]

Competing interpretations of the term "water" within the WEF nexus have been another source of confusion in recent years. Early descriptions of the nexus seemed to interpret "water" as encompassing only freshwater supplies.[14] This focus on freshwater resources is sensible given freshwater's unique importance in agriculture and energy generation and given that ocean water supplies are only growing more abundant as sea levels rise.

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11 *See* HOLGER HOFF, UNDERSTANDING THE NEXUS: BACKGROUND PAPER FOR THE BONN 2011 NEXUS CONFERENCE 16 (2011), https://mediamanager.sei.org/documents/Publications/SEI-Paper-Hoff-UnderstandingTheNexus-2011.pdf (displaying "water supply security" as an appendage on a WEF nexus diagram, with "available water resources" in the middle of the diagram).

12 *See id.* (declaring that "[w]ater plays a central role in the nexus").

13 *See* Cameron Holley & Amanda Kennedy, *Governing the Energy-Water-Food Nexus: Regulating Unconventional Gas Development in Queensland, Australia*, 59 JURIMETRICS J. 233, 236 (2019) (arguing that, "[b]ecause the nexus approach embraces multiple sectors (e.g., energy, water, food), it is more holistic than earlier governance approaches, which preferred certain sectors over others (e.g., the water focus of integrated water management)" and that this "sector 'neutrality' . . . [has] found particular currency in global economic and environmental security discussions"); Jürgen Mahlknecht et al., *Water-Energy-Food Security: A Nexus Perspective of the Current Situation in Latin America and the Caribbean*, ENERGY, Dec. 2019, at 2; Yuan Chang et al., *Quantifying the Water-Energy-Food Nexus: Current Status and Trends*, ENERGIES, 2016, at 2.

14 *See, e.g.*, WORLD ECON. F. WATER INITIATIVE, *supra* note 3, at 1 ("As economies grow, more of the freshwater there is left available is demanded by energy, industrial, and urban systems.").

However, some scholars have since interpreted the "water" arm as being broad enough to encompass even the ocean itself—a very different type of natural resource.[15] Such expansions of the "water" arm may be an enticing means of extending the WEF nexus terminology to a wider range of cross-resource conflicts, but they also inject more imprecision and ambiguity into an already-fuzzy structure.

Of course, the one benefit of the WEF nexus framework's malleability is that it allows the model to adapt as resource management priorities change over time. For instance, as climate change worries have mounted in recent years, decarbonization efforts have increasingly found room within the nexus construct. At least one adaptation of the nexus framework has even gone so far as to place climate change adaptation directly in the center of the nexus diagram.[16] Some others have added "climate" to the end of the nexus's name, as though climate security were a fourth nexus arm.[17] This growing impulse to incorporate climate security into the WEF nexus is hardly surprising: decarbonization activities may not be critical to sustaining day-to-day life in the short run, but they are measurable and marketable outputs that are crucial to long-term sustainability and thus arguably warrant inclusion alongside the three original nexus resources.[18] Therefore, treating climate security as a fourth nexus arm might better reflect the growing reality that decarbonization efforts are unavoidably intertwined with long-term

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15 *See, e.g.*, Robin Kundis Craig, *Harvest the Wind, Harvest Your Dinner: Using Law to Encourage an Offshore Energy-Food Multiple-Use Nexus*, 59 JURIMETRICS J. 61, 61 (2018) (using WEF nexus terminology in connection with an analysis of conflicts between offshore wind farms and open ocean marine aquaculture).

16 *See, e.g.*, JON O'RIORDAN, ROBERT W. SANDFORD & DEBORAH HARFORD, THE CLIMATE NEXUS: WATER, FOOD, ENERGY AND BIODIVERSITY IN A CHANGING WORLD (2016).

17 *See, e.g.*, THE WATER, FOOD, ENERGY AND CLIMATE NEXUS: CHALLENGES AND AN AGENDA FOR ACTION (Felix Dobbs & Jamie Bartram eds., 2016).

18 For instance, reductions in greenhouse gas emissions are often measured in "carbon dioxide equivalents." *See* Zeke Hausfather, *Understanding Carbon Dioxide Equivalence*, YALE CLIMATE CONNECTIONS (Jan. 20, 2009), https://yaleclimateconnections.org/2009/01/common-climate-misconceptions-co-equivalence. The existence of robust carbon offset markets is evidence of the measurability and marketability of this unique type of resource. *See, e.g.*, Anna Gross et al., *Boom Times are Back for Carbon Offsetting Industry*, FIN. TIMES (Dec. 13, 2019), https://www.ft.com/content/7e4665a2-1776-11ea-8d73-6303645ac406 (describing the size and growth of carbon offset markets).

water, energy, and food security.[19] The decarbonization policy efforts of the United Nations Framework Convention on Climate Change (UNFCCC), including the 2015 Paris Agreement, and United Nations (U.N.) member states' inclusion of "climate action" within the 2030 Agenda for Sustainable Development Goals arguably support calls for adding climate security to the WEF nexus.[20] On the other hand, adding a fourth policy goal to the WEF nexus construct would divert attention from its original three-pronged focus and might thereby weaken the framework's capacity to impact water, energy, and food security policy.

### C. Untapped Potential

Despite its imperfections, the WEF nexus can be a valuable model for showcasing and analyzing some of the world's most pressing resource management challenges. As climate change impacts intensify and developing economies place ever more strain on the planet's limited supplies of core resources, the need for such analytic tools will only grow. By elegantly emphasizing the interconnectedness of water, energy, and food security, the WEF nexus helps to keep these linkages and the need to more holistically manage them front-of-mind.

Still, the WEF nexus construct could have even greater influence if it focused as much on constructive cross-resource interactions as it currently focuses on tradeoffs. Laws and policy strategies that more intently leverage synergistic nexus resource interactions are not the panacea for achieving global water, energy, and food security, but they could help communities and nations circumvent some painful tradeoffs among nexus resources. In recognition of that potential, the balance of this Article centers on policy ideas for expanding this more optimistic and entrepreneurial approach to WEF nexus governance.

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[19] Although this Article does not incorporate decarbonization as a fourth nexus arm, it does consciously integrate decarbonization goals into much of its analysis.

[20] *See generally* Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 12, 2015, T.I.A.S. No. 16-1104; UNITED NATIONS, *The 17 Goals*, https://sdgs.un.org/goals (last visited Mar. 3, 2023).

## II. ZERO-SUM VERSUS POSITIVE-SUM NEXUS INTERACTIONS

A key first step toward a more holistic approach to WEF nexus governance is to recognize the distinction between zero-sum and positive-sum nexus resource interactions. Most existing WEF nexus governance research views the nexus as what game theorists might call a "zero-sum" game: it examines how increasing the security of one nexus resource tends to adversely impact the security of other nexus resources and explores how various forms of integrated management might better account for these cross-effects.[21] In contrast, "positive-sum" nexus governance focuses on identifying, developing, and promoting innovations that improve the security of one or more nexus resources without negatively affecting the security of the others.[22] The following subsections employ some basic microeconomics diagrams to elaborate on this distinction and use real-world examples to highlight the potential benefits of placing greater attention on positive-sum approaches.

### A. WEF Nexus Interactions as a Zero-Sum Game

As stated above, the earliest academic research referencing the WEF nexus tended to center primarily on zero-sum nexus resource interactions.[23] This zero-sum view of the nexus has continued to undergird much of the WEF nexus literature produced over the past

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[21] John von Neuman and Oskar Morgenstern are generally credited with creating game theory—a concept that has appeared in legal academic scholarship for decades. Zero-sum games are a primary type of game within that body of literature. *See* Shalanda Baker et al., *Beyond Zero-Sum Environmentalism,* 47 ENV'T L. REP. NEWS & ANALYSIS 10328, 10338 (2017) (citing THOMAS S. FERGUSON, GAME THEORY 6 (2011)).

[22] A third category of interactions—"negative-sum" interactions—describes those that ultimately reduce the aggregate production capacity for at least one nexus resource without commensurately increasing capacity for any others. *See* Daniel A. Bent, *Game Theory Explains How Mediation Can Trump Litigation,* MONDAQ (June 1, 2001), https://www.mondaq.com/unitedstates/litigation-mediation-arbitration/11840/game-theory-explains-how-mediation-can-trump-litigation (describing a "negative-sum game" as one in which "both the winner and loser can end up significantly worse off than when they started").

[23] *See, e.g.*, WORLD ECON. F. WATER INITIATIVE, *supra* note 3, at 10–11 ("[T]hese various issues are all highly interlinked, and solutions to one can in fact worsen another . . . When water use is taken into account together with carbon emissions, some renewable energy sources begin to look less sustainable . . . Energy security and water security thinking are not yet aligned.").

decade.[24] Graphically depicting zero-sum nexus resource interactions and contrasting those depictions with representations of positive-sum interactions helps to emphasize the fundamental differences between them.

### 1. Inflexible Resource Tradeoffs

One of the simplest ways to graphically portray interactions among nexus resources is to place them on a simple production possibility frontier diagram. Introductory economics textbooks have featured versions of these diagrams describing hypothetical tradeoffs for decades.[25] However, at least one pair of researchers has recently begun employing similar diagrams to emphasize the zero-sum nature of some empirically observed WEF nexus interactions. In a 2016 article, Debra Perrone and George Hornberger plotted empirical data on simple two-axis graphs to depict certain tradeoffs between irrigated agricultural production and hydroelectric generation in Sri Lanka, calling their diagrams "tradeoff frontiers."[26]

It is relatively easy to use tradeoff frontiers to depict WEF nexus resource interactions and the potential effects of policy changes on those relationships. To illustrate: suppose the government of a hypothetical isolated country was considering a new law that would require petroleum refiners within the country to mix more corn-based ethanol into their gasoline products.[27] Enacting such a requirement would likely be a zero-sum or nearly zero-sum move: It would increase aggregate energy supplies by causing more water, land, and other resources to flow to the manufacture of an energy product but it would also reduce food production capacity.

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[24] *See, e.g.*, Perrone & Hornberger, *supra* note 2, at 1 ("As the demand for each resource increases, the interrelationships among food, energy, and water become more pronounced so that a solution to address scarcity in one resource cannot be achieved without impact on the others. We call this the food security, energy security, and water security trilemma.").

[25] For instance, Paul Samuelson displayed "guns-versus-butter" tradeoffs on production possibilities frontiers. *See generally* PAUL A. SAMUELSON, ECONOMICS 19–21 (10th ed. 1976).

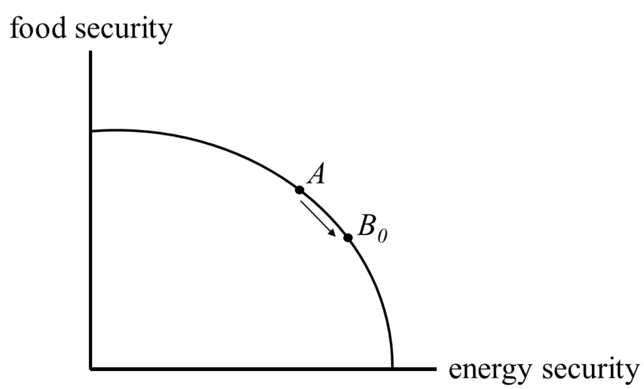
[26] *See generally* Perrone & Hornberger, *supra* note 2, at 5.

[27] The federal Renewable Fuel Standard in the United States is one example of this type of ethanol requirement. *See* Energy Independence and Security Act of 2007, 42 U.S.C. § 202.

A two-dimensional tradeoff frontier depicting the inverse relationship between food security and energy security and the potential impact of a new ethanol fuel requirement on the balance between these two nexus arms is illustrated in Figure A below. The initial balance between food security and energy security is labeled on the tradeoff frontier as Point *A*. All else equal, enacting the new ethanol requirement would create additional artificial market demand for corn-based ethanol. This heightened demand would increase corn prices, thereby incentivizing farmers to shift some of their land and other resources from food crop production to the cultivation of corn for sale to ethanol manufacturers.[28] This change in the balance of food security and energy security within the jurisdiction is illustrated in Figure A as a migration along the jurisdiction's tradeoff frontier from Point *A* to Point $B_0$.

Figure A:

Effect of a New Ethanol Fuel Requirement on a Region's Food-Energy Nexus Tradeoff Frontier




Of course, the hypothetical ethanol fuel requirement just described would affect more than just food security. Among other things, it would impact the jurisdiction's water security as well. Although ethanol production's impacts on freshwater security can

[28] As of 2013, as much as 40% of the corn grown in the United States was used to produce biofuels. *See* Jennifer Mosquera, *Corn, Cows, and Cash: How Farming Subsidies Work and What They Could Potentially Achieve*, 34 J. LAND USE & ENV'T. L. 191, 202 (2018) (citing Jonathan Foley, *It's Time to Rethink America's Corn System*, SCI. AM. (Mar. 5, 2013), https://www.scientificamerican.com/article/time-to-rethink-corn).

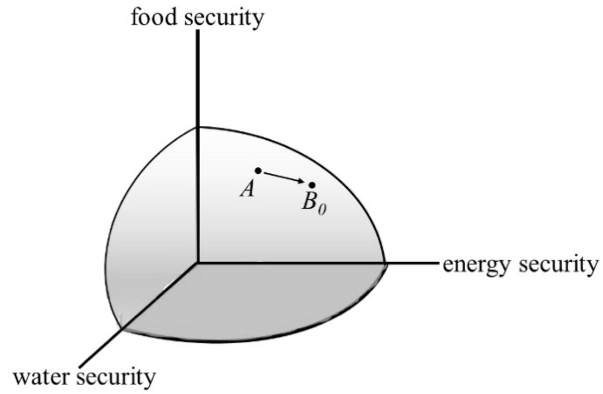
vary greatly across regions, such a requirement would likely reduce the availability of potable freshwater in many parts of the globe.[29] In such settings, a third axis would need to be added to the tradeoff frontier in Figure A to show the new ethanol requirement's impact on freshwater supplies. A rudimentary two-dimensional representation of such a three-dimensional diagram appears in Figure B below. The new ethanol law would cause the balance of food security, energy security, and water security within the jurisdiction to move along the surface of this three-dimensional tradeoff frontier from Point *A* to Point $B_0$. Although it's difficult to illustrate this migration in two dimensions, the relocation to Point $B_0$ reflects outward movement along the energy and water axes and downward movement along the food axis. Again, such a move is zero-sum or nearly zero-sum because, all else equal, increasing energy security through this strategy necessitates commensurate decreases in food security and water security.[30]

[29] *See* Leah Stiegler, Comment, *Avoiding the Catch-22: Reforming the Renewable Fuel Standard to Protect Freshwater Resources and Promote Energy Independence*, 48 U. RICH. L. REV. 1063, 1074–83 (2014) (describing ethanol production's impacts on freshwater resources).

[30] Of course, a commonly touted benefit of ethanol requirements is their potential to reduce aggregate greenhouse gas emissions. *See* M. FLUGGE ET AL., A LIFE-CYCLE ANALYSIS OF THE GREENHOUSE GAS EMISSIONS OF CORN-BASED ETHANOL 3 (2017) (citing an EPA Regulatory Impact Analysis study concluding that the greenhouse gas "emissions associated with production of a unit of corn-based ethanol from a state-of-the-art natural gas powered refinery would be about 21 percent lower than the emissions from an energy equivalent quantity of an 'average' gasoline in 2005"). One could conceive of a four-armed WEF nexus framework incorporating these effects, although the diagram in Figure B would need a fourth dimension to graphically depict them.

Figure B:

Effect of a New Ethanol Requirement on a Region's Water-Energy-Food Nexus Tradeoff Frontier




Analyses of zero-sum nexus interactions tend to focus primarily on whether particular actions that cause movements across WEF nexus tradeoff frontiers like those depicted in Figures A and B are justifiable.[31] Such analyses can certainly be valuable to the extent they promote more efficient management of resource interactions that are unavoidably zero-sum.

2. Common Zero-Sum Nexus Conflicts and Their Governance Challenges

Much of the WEF nexus governance literature published to date focuses on a long list of zero-sum tradeoffs among nexus resources akin to those featured in the ethanol example above. Growing, harvesting, processing, and distributing food is often very

[31] *See, e.g.*, Mark Walker, *Breaching Dams 'Must Be an Option' to Save Salmon, Washington Democrats Say*, N.Y. TIMES (Aug. 31, 2022), https://www.nytimes.com/2022/08/31/us/politics/salmon-dams.html (describing debates over whether to decommission certain hydroelectric dams along the Snake River in the Pacific Northwest to preserve endangered salmon runs that struggle to survive without unimpeded river flows).

energy- and water-intensive.[32] Thermal generating plants generate electricity but also emit carbon dioxide and are among the nation's greatest consumers of water.[33] Hydraulic fracturing and other unconventional oil and gas extraction techniques consume enormous quantities of water as well.[34] Some types of biomass and biofuel production require large amounts of water and land and can thus displace food production.[35] Desalination plants produce freshwater but consume tremendous supplies of energy to do so and may also emit greenhouse gases unless low-carbon energy sources are used.[36] Hydroelectric generating facilities can impact water supplies and thus indirectly interfere with food production in some cases.[37] Even some of the most clean and low-carbon forms of

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32 *See, e.g.*, RALPH E.H. SIMS ET AL., ISSUE PAPER: ENERGY-SMART FOOD FOR PEOPLE AND CLIMATE, at III (2011) (noting that "[t]he food sector currently accounts for around 30 percent of the world's total energy consumption" and "contributes over 20 percent of total GHGs emissions"); *see also Aquastat—FAO's Global Information System on Water and Agriculture*, FAO, http://www.fao.org/aquastat/en/overview/methodology/water-use (last visited Mar. 3, 2023) (noting that agricultural activities account for 69 percent of all global freshwater withdrawals).

33 Thermal power plants account for roughly one third of all freshwater withdrawals in the United States. *See* Ashleen Knutsen, *The U.S. Energy System Uses a Lot of Water — But Exactly How Much?*, USC NEWS (Sep. 12, 2018), https://news.usc.edu/148541/energy-consumption-requires-a-lot-of-water-but-just-how-much; Greg A. Barron-Gafford et al., *Agrivoltaics Provide Mutual Benefits Across the Food-Energy-Water Nexus in Drylands*, 2 NATURE SUSTAINABILITY 848, 848 (2019); *see also* Benjamin K. Sovacool et al., *Troubled Waters: The Quest for Electricity in Water-Constrained China, France, India and the United States*, 21 N.Y.U. ENV'T L.J. 409, 412–13 (2014) (noting a 2006 incident in which high water temperatures in the Mississippi River forced certain Midwest nuclear power plants to temporarily ramp down electricity production).

34 *See generally* Lorenzo Rosa et al., *The Water-Energy Nexus of Hydraulic Fracturing: A Global Hydrologic Analysis for Shale Oil and Gas Extraction*, 6 EARTH'S FUTURE 1, 1–3 (2018).

35 *See, e.g.*, J. Popp et al., *The Effect of Bioenergy Expansion: Food, Energy, and Environment*, 32 RENEWABLE & SUSTAINABLE ENERGY REV. 559, 575 (2014) (finding that "increasing demand for suitable land in which this biomass needs to grow competes with the need for food production" and that "[t]his is causing conflicts between land use for food and those for producing bioenergy crops.").

36 *See, e.g.,* Carey W. King et al., *Thirst for Energy*, 1 NATURE GEOSCIENCE 283, 284 (2008) (noting that "treatment of brackish ground water and sea water requires as much as 10–12 times the energy use of standard drinking-water treatment").

37 *See generally* Perrone & Hornberger, *supra* note 2, at 3 (describing adverse impacts of hydroelectric facilities on food production in Sri Lanka); *see also* Alejandro Vergara et al., *The Water-Energy Nexus in Chile: A Description of the*

energy generation such as concentrating solar power plants can use up precious freshwater resources.[38]

Governance strategies aimed at better managing zero-sum nexus resource interactions like those just described often involve progressions toward more centralized and cohesive resource governance. The World Economic Forum's initial 2011 report on the WEF nexus seemed to specifically call for this approach, arguing that conflicts among nexus resources are so "[i]nterlinked" that they "[m]ust [b]e [a]ddressed in [t]andem."[39] Other WEF nexus researchers have echoed this prescription in subsequent years, advocating for more "integrated and coordinated governance arrangements" for nexus resources.[40] Still others have declared the need for a "whole-of-system" governance approach.[41] The general rationale behind these consolidated governance strategies is that separate, siloed governance structures cannot effectively account for the full panoply of consequences resulting from activities involving any one nexus resource.[42] More centralized governance is thus billed as a way to ensure that effects on all nexus resources get ample consideration in policymaking decisions.[43]

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*Regulatory Framework for Hydroelectricity*, 35 J. ENERGY & NAT. RES. L. 463, 463 (2017) (describing energy-water nexus governance issues for hydroelectric projects in Chile).

38 *See* Paolo D'Odorico et al., *The Global Food-Energy-Water Nexus*, 56 REVS. OF GEOPHYSICS 456, 484–85 (2018) (asserting that "[c]oncentrating solar power . . . has water consumption levels similar to those of thermoelectric power plants").

39 *See* WORLD ECON. F. WATER INITIATIVE, *supra* note 3, at 10.

40 Holley & Kennedy, *supra* note 13, at 237.

41 *See, e.g.*, J. Rockström et al., *The Unfolding Water Drama in the Anthropocene: Towards a Resilience-Based Perspective on Water for Global Sustainability*, 7 ECOHYDROLOGY 1249, 1257 (2014).

42 *See* Claudia Pahl-Wostl, *Governance of the Water-Energy-Food Security Nexus: A Multi-Level Coordination Challenge*, 92 ENV'T SCI. & POL'Y 356, 356 (2019) (arguing that interrelationships between water security, food security, and energy security have "often been neglected in sectoral policies with the consequence of persistent trade-offs rather than identification and strengthening of synergies").

43 *See, e.g.*, Sharon B. Megdal & Jacob D. Petersen-Perlman, *Decentralized Groundwater Governance and Water Nexus Implications in the United States*, 59 JURIMETRICS J. 99, 118 (2018) (emphasizing the "need for states to collaborate with sub-state, federal, and neighboring jurisdictions on groundwater challenges relating to food, energy and climate" to avoid "piecemeal consideration of water-food-energy-climate nexus issues").

Unfortunately, attempts to centralize the oversight of the numerous complex tradeoffs involving water security, energy security, and food security present their own governance challenges. Water security governance alone requires a tremendous amount of specialized knowledge. Indeed, some water governance tasks—such as major stream adjudications in the United States—can be so multi-faceted that for years they consume nearly all of a government entity's time.[44] Similar complexities already complicate energy law and agricultural law as well.[45] Consolidating the governance of multiple nexus resources under a single roof tends to also create greater distance from on-the-ground stakeholders, who arguably have the best factual knowledge needed to effectively address specific conflicts.

These obstacles and challenges have led some academicians to paint the WEF nexus in a pessimistic light, labeling it a "trilemma"[46] or characterizing it as a "super-wicked problem."[47] Such gloomy views of the WEF nexus are not only incomplete for reasons outlined below; they also fuel a pernicious broader tendency toward "zero-sum thinking" in the context of environmental policy.[48]

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44 Other writers have emphasized this point. *See, e.g.*, Loë & Patterson, *supra* note 4, at 91 (commenting that "[i]ntegration challenges within any single resource sector are immense" and that "[t]hese integration challenges are much greater when considering multiple resource sectors simultaneously").

45 For example, complex debates over policies governing the transition from conventional energy sources such as fossil fuels and nuclear power to cleaner and more renewable energy sources such as wind and solar energy have persisted for decades. *See generally* TROY A. RULE, RENEWABLE ENERGY: LAW, POLICY AND PRACTICE 969 (2d ed. 2021). Tremendous complexities also surround efforts to improve federal agricultural policy, where regional differences and numerous other factors and objectives greatly complicate policymaking. *See, e.g.*, Jess R. Phelps, *Conservation, Regionality, and the Farm Bill*, 71 ME. L. REV. 293, 295 (2019) (describing how "competing policy objectives" and "growing policy divides" complicate the "complex legislative process" of enacting federal agricultural legislation).

46 *See* D'Odorico, *supra* note 38, at 458. *See also* David Tilman et al., *Beneficial Biofuels—The Food, Energy, and Environment Trilemma*, 325 SCIENCE 270 (2009) (using the term "trilemma" to describe food-water-energy interrelations but without using the term "nexus").

47 *See* Claire Hoolohan et al., *'Aha' Moments in the Water-Energy-Food Nexus: A New Morphological Scenario Method to Accelerate Sustainable Transformation*, 148 TECH. FORECASTING & SOC. CHANGE 1, 2 (2019).

48 Other legal academicians have highlighted the adverse influence of zero-sum thinking in environmental policy. *See, e.g.*, Baker et al., *supra* note 21 (critiquing the use of "zero-sum thinking" in several environmental policy areas).

### B. Positive-Sum Nexus Interactions

In contrast to zero-sum WEF nexus governance, a second and fundamentally different type of nexus governance that this Article calls "positive-sum nexus governance" has separately emerged in recent years. Rather than taking ostensible nexus resource tradeoffs as a given, positive-sum nexus governance strategies search for ways to leverage technologies or targeted capital investment to expand existing tradeoff frontiers involving WEF nexus resources. Such strategies involve centralized governance only to the extent necessary to identify and exploit value-creating interactions among nexus resources.

#### 1. Synergistic Relationships and Expandable Tradeoff Frontiers

Positive-sum WEF nexus governance strategies embrace the view that, like the production possibility frontiers often studied in introductory economics courses, many WEF nexus tradeoff frontiers are expandable. They optimistically embrace the notion that various factors and changes—including policy changes that promote strategic investments and technological innovation—can potentially shift existing frontiers outward over time.[49]

To emphasize this idea, let us return to the hypothetical legislative body described in Section II.A.1 above that contemplated enacting a new ethanol fuel requirement. Suppose that, in lieu of enacting new ethanol rules, the legislature focused instead on enacting policies capable of increasing energy security without diminishing supplies of food or water resources. Such positive-sum policy strategies are often comparatively more difficult to find, but they do exist in many contexts and are becoming increasingly common as technologies advance over time. For instance, these hypothetical legislators might consider enacting laws to promote the development of "agrivoltaics"—solar photovoltaic arrays installed above agricultural fields that can potentially increase yields for shade-loving crops, reduce irrigation demands, and displace carbon-emitting electricity generation.[50] In the right settings, such policies

[49] *See* PAUL A. SAMUELSON & WILLIAM D. NORDHAUS, ECONOMICS 9–13 (19th ed. 2009) (describing and illustrating how an "increase in inputs, or improved technological knowledge, enables a country to produce more of all goods and services, thus shifting out the [production possibility frontier]").

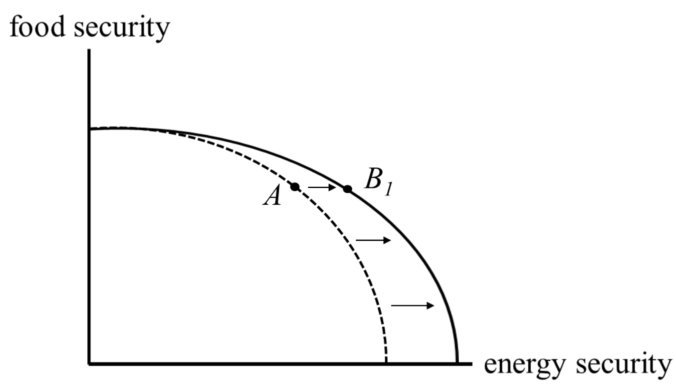
[50] For a more detailed description of agrivoltaics projects, *see infra* notes 65–69 and accompanying text.

can be positive-sum from a WEF nexus perspective: they can unlock combinations of water, food, and energy security that extend beyond previous tradeoff frontiers.

Tradeoff frontier diagrams like those shown above can effectively illustrate the distinct impacts of positive-sum nexus policies. Figure C below is a two-resource tradeoff frontier depicting the potential effect of a newly enacted agrivoltaics development subsidy program on food and energy security. As shown in Figure C, by driving new private investment in agrivoltaics projects, the policy would likely shift the food-energy tradeoff frontier outward along the x-axis—a reflection of this new technology's ability to increase energy production while having a smaller impact on food production capacity than was previously possible. The newly shifted tradeoff frontier in Figure C represents a complete set of previously unachievable combinations of food and energy production, including the combination labeled Point $B_1$

Figure C:

Effect of an Agrivoltaics Subsidy Program on a Region's Food-Energy Nexus Tradeoff Frontier



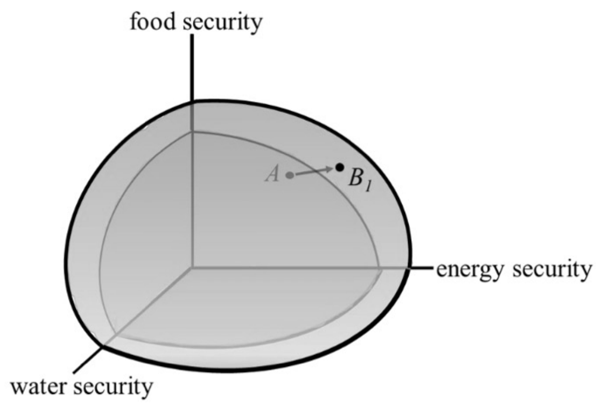

It is similarly possible to illustrate the potential impact of an agrivoltaics subsidy program on freshwater availability by adding a third dimension to the tradeoff frontier in Figure C. As described in more detail in Section II.C.1 below, agrivoltaics can also conserve water supplies by shading fields and thereby reducing the evaporation of irrigation water.[51] Figure D below illustrates this

[51] *See infra* notes 65–69 and accompanying text.

potential outward shift and movement from Point *A* to Point $B_1$ on the newly expanded three-dimensional tradeoff frontier. Point $B_1$ represents just one of many improved combinations of food, energy, and water security attainable through the new agrivoltaics policy.

Figure D:

Effect of an Agrivoltaics Subsidy Program on a Region's Water-Energy-Food Tradeoff Frontier




2. Historical Examples of Positive-Sum Nexus Moves

Positive-sum moves involving WEF nexus resources are nothing new; technologies and capital investments have been steadily pushing out the planet's WEF nexus tradeoff frontier for a very long time. The cumulative result of all of that expansion is a global WEF nexus tradeoff frontier that is far more expansive now than it was a century ago or even a decade ago. Indeed, the water security, food security, and energy security challenges facing humankind today would be far more severe and devastating if not for those countless earlier improvements.

Improvements in irrigation systems and practices and certain other agricultural technologies are one class of advancements that has gradually expanded the WEF nexus tradeoff frontier over the years. Although humans have been using irrigation techniques for at least six thousand years to increase crop yields,[52] irrigation

[52] *See* J.B. Ruhl, *Farms, Their Environmental Harms, and Environmental Laws*, 27 ECOLOGY L.Q. 263, 266 n.2 (2000) (citing Mohamed T. El-Ashry et al., *Salinity Pollution from Irrigated Agriculture*, 40 J. SOIL & WATER CONSERVATION

practices have gradually progressed from rudimentary flood irrigation to today's modern drip systems and low-energy precision application methods.[53] The increased use of fertilizers and pesticides—despite their potential environmental and health hazards—and the mechanization of many formerly labor-intensive farming activities such as planting and harvesting have also been positive-sum nexus moves in many contexts.[54]

Windmills and watermills are two other relatively old technologies that have facilitated positive-sum WEF nexus interactions for centuries in some settings. Long before modern wind turbines began producing electric current, windmill pumps were harnessing the carbon-free energy in wind to improve groundwater access and aid food production on farms across the world.[55] Water-powered grain mills were likewise assisting in food production by enabling communities to grind grain many years before electricity-powered systems replaced them.[56] Both of these types of technologies expanded nexus tradeoff frontiers by furnishing innovative ways to improve food and water security.

Many historic hydroelectric dam projects were also positive-sum nexus moves. One example of this type of move is the U.S.

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48, 48 (1985)) (describing how ancient Sumerian farmers damaged soils, leading to the civilization's decline roughly 6,000 years ago).

[53] *See* Clifford J. Villa, *California Dreaming: Water Transfers from the Pacific Northwest*, 23 ENV'T L. 997, 1014–15 (1993) (describing low-energy precision application systems as systems that "use[] drop tubes hanging from sprinkler arms which, like the drip systems, deliver water close to the crops" and "in conjunction with other water conservation practices ha[ve] shown efficiencies up to ninety-five percent").

[54] *See Fertilizers and Pesticides*, U.S. DEP'T OF AGRIC., https://www.ers.usda.gov/topics/farm-practices-management/fertilizers-pesticides (last updated Oct. 30, 2019). Concededly, a few agricultural innovations have brought negative impacts as well. For instance, mechanization and fertilizer use have likely enabled less water- and energy-intensive food production but have increased carbon dioxide emissions. *See* EPA, NATIONAL EMISSIONS FROM LAWN AND GARDEN EQUIPMENT (2015).

[55] *See* ADAM LUCAS, WIND, WATER, WORK: ANCIENT AND MEDIEVAL MILLING TECHNOLOGY 101–104 (2006).

[56] *See* Vince DiNoto, *Water Powered Mills*, ARCGIS (Jan. 24, 2020), https://storymaps.arcgis.com/stories/f7d002f861064ef086c39f97c19d7dd2 (describing the importance of water-powered grain mills in many early American communities); Kris De Decker, *Wind Powered Factories: History (and Future) of Industrial Windmills*, LOW-TECH MAG. (Oct. 9, 2009, 1:12 PM) https://www.lowtechmagazine.com/2009/10/history-of-industrial-windmills.html.

government's formation of special agencies such as the Bonneville Power Administration in the 1930s to build hydroelectric dams and supporting infrastructure in certain regions of the country.[57] To a large extent, these new dams improved energy, water, and food security across entire regions and had positive net impacts on carbon emissions.[58]

Even canal infrastructure development has pushed out WEF nexus tradeoff frontiers by improving water and food security in arid regions of the world. For instance, in portions of Arizona in the Southwestern United States, the Native American Hohokam people built extensive canal systems along the Salt and Gila Rivers long before European colonization of that region.[59] These canals improved tribe members' water and food security, enabling them to irrigate and grow crops in a harsh desert landscape.[60] Incredibly, portions of their ancient canal system are still helping to supply freshwater to parts of Arizona's Phoenix Valley today.[61]

It bears mentioning that the historic positive-sum WEF nexus moves just described were far from perfect: many of them degraded land resources, harmed wildlife populations, or caused other adverse environmental impacts that lie outside the scope of the WEF nexus framework. For instance, agricultural pesticides often enhance crop yields in ways that simultaneously improve food security and water security, but they can also contaminate soil and air and threaten wild animal species.[62] In light of these risks, policymakers will need to conscientiously guard against such

57 *See Our History*, BONNEVILLE POWER ADMIN., https://www.bpa.gov/about/who-we-are/our-history (last visited Mar. 3, 2023).

58 *See, e.g.*, Rhett B. Larson, *Reconciling Energy and Food Security*, 48 U. RICH. L. REV. 929, 955–56 (2014) (describing the positive impacts of the construction of Tennessee Valley Authority dams on water security and on food security (by greatly benefiting agricultural activities) in portions of the Southeastern United States).

59 *See* John E. Thorson et al., *Dividing Western Waters: A Century of Adjudicating Rivers and Streams*, 8 U. DENV. WATER L. REV. 355, 390–91 (2005).

60 *See id.*

61 *See* Edward Sullivan & A. Dan Tarlock, *The Western Urban Landscape and Climate Change*, 49 ENV'T L. 931, 962–63 (2019); Kim Whitley & Jeri Ledbetter, *Hohokam Canal System*, N. ARIZ. UNIV.: ARIZ. HERITAGE WATERS (2011), http://www. azheritagewaters.nau.edu/loc_hohokam.html (last visited Feb. 19, 2023) (noting that many of the tribe's canals are "still in use").

62 *See, e.g.*, Md. Wasim Aktar et al., *Impact of Pesticides Use in Agriculture: Their Benefits and Hazards*, 2 INTERDISC. TOXICOLOGY 1, 5–7 (2009).

collateral impacts when devising new positive-sum nexus strategies in future years.

### C. Emerging Positive-Sum Nexus Strategies

In recent decades, certain technologies have emerged that are beginning to unlock new possibilities for expanding WEF nexus tradeoff frontiers. Ironically, many of these new innovations are occurring in the energy sector, suggesting that—at least for now—positive-sum nexus governance is more energy-centric than water-centric. For instance, increasingly affordable wind energy technologies can extend tradeoff frontiers by replacing carbon- and water-intensive fossil-fuel energy generation with minimal adverse impacts on food production. Meanwhile, new solar energy and energy storage technologies are beginning to unlock even more synergistic interactions among nexus resources. However, at this early stage, many development strategies aimed at exploiting these synergies are still relatively expensive and may thus need government support to mature to their full potential.[63] The following are brief descriptions of a few of these promising technologies.

#### 1. Leveraging Solar Photovoltaic Technologies

Relatively recent advancements in solar photovoltaic (PV) technologies and the falling price of PV modules have recently introduced new types of opportunities for positive-sum nexus interactions. Like wind farms, solar PV installations often expand nexus tradeoff frontiers in a general sense to the extent that they displace more water-intensive thermal electricity generation. As highlighted above, power plants fueled by coal or natural gas not only generate far more greenhouse gases, but often also withdraw much more water from freshwater sources than PV projects, leaving

[63] *See, e.g.*, Emiliano Bellini, *Cost Comparison Between Agrivoltaics and Ground-Mounted PV*, PV MAG. (Mar. 26, 2021), https://www.pv-magazine.com/2021/03/26/cost-comparison-between-agrivoltaics-and-ground-mounted-pv (describing a recent study finding that "agrivoltaic projects are still considerably more expensive than ground-mounted PV plants"); Wayne Hicks, *Declining Renewable Costs Drive Focus on Energy Storage*, NREL (Jan. 2, 2020), https://www.nrel.gov/news/features/2020/declining-renewable-costs-drive-focus-on-energy-storage.html (describing various energy storage strategies and ongoing challenges in quantifying their costs and benefits).

less for drinking or food production.[64] Solar PV technologies can facilitate synergistic interactions with other WEF nexus resources in several more specific ways as well.

"Agrivoltaic" projects like those highlighted in the examples in Section II.B.1 above are one promising new way to leverage positive-sum nexus resource interactions. Agrivoltaic projects are ground-mounted solar PV arrays installed above food crops on agricultural lands.[65] Such projects can obviously produce energy and help to decarbonize energy production to the extent that they displace carbon-based electricity generation. They can also have beneficial effects on the other two "arms" of the WEF nexus by increasing yields for shade-loving crops and reducing evaporation in irrigated fields.[66] Incredibly, the vegetation beneath the panels even lowers ground temperatures, enabling the panels to generate more power.[67] One study found similar benefits from installing solar panels above non-irrigated pasture lands in semi-arid climates.[68] Agrivoltaics are admittedly not a viable option in some regions and may require significant expansions of transmission infrastructure, but they could help to expand nexus tradeoff frontiers when deployed in appropriate settings. According to a recent Oregon State University study, solar panels covering just one percent of the world's agricultural land would supply enough power to meet the entire planet's electricity demand.[69]

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64 Some water withdrawn for coal- or gas-fired electricity generation eventually returns to natural watercourses. *See* Barron-Gafford et al., *supra* note 33; Sovacool et al., *supra* note 33, at 411–12 n.1 and accompanying text.

65 *See* Christian Dupraz et al., *Combining Solar Photovoltaic Panels and Food Crops for Optimising Land Use: Towards New Agrivoltaic Schemes*, 36 RENEWABLE ENERGY 2725, 2725, 2727 (2011).

66 *See id.* at 2726–27.

67 *See* Barron-Gafford et al., *supra* note 33, at 849–51 (finding that agrivoltaic PV panels were about 9 degrees Celsius cooler during the day than ordinary ground-mounted panels, resulting in greater energy productivity).

68 *See* Elnaz Hassanpour Adeh et al., *Remarkable Agrivoltaic Influence on Soil Moisture, Micrometeorology and Water-Use Efficiency*, PLOS ONE, Nov. 1, 2018, at 1, 13 (describing a study that found "dramatic gains in productivity" through agrivoltaics installations in certain "semi-arid pastures with wet winters" due mostly to "increased water use efficiency").

69 *See* Andrew Burger, *Agrivoltaic Research, Applications Could Reconcile Trade-Offs at the Water-Food-Energy Nexus*, SOLAR MAG., https://solarmagazine.com/agrivoltaic-research-applications-could-reconcile-trade-offs-at-the-water-food-energy-nexus (last visited Mar. 3, 2023) [hereinafter Burger, *Agrivoltaic Research*].

"Floatovoltaics," or solar PV arrays covering water, can similarly unleash positive-sum nexus interactions in certain environments. Particularly in arid regions of the world, installing solar panels above reservoirs or canals can reduce the evaporation of freshwater supplies critical for drinking and irrigated food production.[70] The cool temperature of the water also improves solar panel efficiency, thereby facilitating even greater carbon-free electricity production.[71] One floatovoltaics project installed over just 750 meters of a single canal system in India now produces roughly 1.53 GWh of electricity each year while sparing an average of "9 million lit[er]s of water from evaporation" each day.[72] From London to Tokyo, floatovoltaic projects have already begun appearing in recent years.[73] Multiple such projects have likewise been installed in California's wine country, where water is at a particular premium.[74]

As climate change and other factors increasingly threaten honeybee populations, the idea of siting beehives together with solar PV arrays has emerged as another potential strategy that could expand WEF nexus tradeoff frontiers. Bees, which are crucial pollinators of agricultural crops, are suffering major population declines in many regions of the world.[75] This loss of natural pollinators can jeopardize food production.[76] Accordingly, a growing number of developers are growing wildflowers under solar arrays.[77] By providing a valuable habitat for pollinators, these shaded wildflower fields can actually increase crop yields on nearby

[70] *See* Eden Cohen & Ryan Hogan, *Made in the Shade: Promoting Solar Over Water Projects*, 54 IDAHO L. REV. 101, 104 (2018).

[71] *See id.* at 120.

[72] *See* INT'L RENEWABLE ENERGY AGENCY, RENEWABLE ENERGY IN THE WATER, ENERGY & FOOD NEXUS 18 (2015), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_Water_Energy_Food_Nexus_2015.pdf.

[73] *See* Cohen & Hogan, *supra* note 70, at 118–19.

[74] *See id.*

[75] *See generally* Megan Hall, Note, *The Great "Bee-Pression:" Declining Bee Populations Amid an Ever-Growing Human-Centered World*, 25 DRAKE J. AGRIC. L. 453 (2020) (describing the importance of bees and other pollinators and the policies and other factors causing their populations to decline).

[76] *See generally id.*

[77] *See* Katie Siegner & Genevieve Lillis, *What Businesses Should Know About The Evolution of Rural Solar*, GREENBIZ (Jan. 23, 2020), https://www.greenbiz.com/article/what-businesses-should-know-about-evolution-rural-solar.

lands owned by others—a benefit that may even reduce neighbors' opposition to large solar PV installations in some rural areas.[78]

Solar PV may even create positive-sum nexus effects by adding directly to a community's water supply. Particularly in remote regions that are unconnected to the electrical grid, solar-powered water pumps can dramatically increase water security by enabling access to groundwater resources.[79] Solar water pumps not only dramatically increase access to clean drinking water; they can also supply irrigation water that facilitates much greater food production in some arid climates.[80] And when solar water pumps replace diesel-powered pumps, they also advance decarbonization goals. For these reasons, solar water pumps are increasingly improving water and food security by replacing diesel pumps across the world, including in remote areas of Egypt.[81] Solar-pumped water is also irrigating fields and increasing food production in Senegal,[82] and government officials in India have plans to facilitate the installation of roughly 175,000 such off-grid solar pumps in that country as well.[83]

Eventually, carbon-free solar energy technologies could even improve water security by using sources other than pumped

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[78] *See id*. ("Neighbors who initially opposed a large-scale solar project in their community [were] . . . assuaged by the proliferation of wildflowers planted throughout a Minnesota pollinator-friendly solar project site.").

[79] *See* Chris Warren, *Water from the Sun: Solar-Powered Water Pumps Offer African Farmers a Way Out of Poverty*, GREENTECH MEDIA (Apr. 17, 2018), https:// www.greentechmedia.com/articles/read/water-from-the-sun (describing the potential for solar groundwater pumps to support more profitable agricultural activity in rural Africa).

[80] *See* Miriam Widman, *PV Meets Drinking Water*, PV MAG. (Dec. 1, 2011), https://www.pv-magazine.com/magazine-archive/pv-meets-drinking-water_10005118 (describing the company Tenesol's efforts to deploy solar groundwater pumps to improve drinking water access in Madagascar); *see also* WORLD FOOD PROGRAMME, SOLAR WATER IRRIGATION: ENERGY ACCESS FOR SUSTAINABLE AGRICULTURE (2021), https://docs.wfp.org/ api/documents/WFP-0000133143/download/?_ga=2.241423809.295968496.1669076131-1496112808.1669076131 (describing potential uses of solar water pumps to improve food security).

[81] *See generally* Kerstin Wydra et al., *Nexus Approach to Solar Technology for Energy and Water Supply for Sustainable Rural Development in Egypt: A Review*, 9 J. PHOTONICS FOR ENERGY 1 (2019).

[82] *See* Andrew Burger, *Solar Fields of Green: Researchers Find Symbiosis at the Food-Water-Energy Nexus,* SOLAR MAG., https://solarmagazine.com/solar-fields-of-green-researchers-find-symbiosis-food-water-energy-nexus (last visited Mar. 3, 2023).

[83] *See* Burger*, Agrivoltaic Research*, *supra* note 69.

groundwater. Among other things, solar PV water desalination technologies are beginning to expand nexus tradeoff frontiers by using sunlight to generate potable freshwater from otherwise unusable water sources.[84] At least one company has developed a device that uses solar power to create drinking water from the air.[85]

2. Leveraging Energy Storage Technologies

When combined with wind and solar energy, increasingly powerful and affordable energy storage technologies are further unlocking new opportunities for positive-sum nexus moves. One such opportunity lies in the growing availability of electric farm equipment, which provides hours of potentially carbon-free energy for farmers that is also likely less water-intensive to generate than gasoline.[86] Industrial food production has been a relatively carbon-intensive process over the past century, relying heavily on petroleum-powered tractors, harvesters, and other equipment.[87] As renewable energy sources such as wind and solar fuel an ever greater proportion of the electricity mix in countries across the globe,[88] replacing gas-powered farm equipment with modern electric equipment could ultimately enable farmers to produce crops with far less water consumption and fewer carbon emissions as well.

Increasingly efficient and affordable energy storage technologies are also beginning to benefit food production in

84 *See, e.g.*, Jean Haggerty, *A New Solar Desalination System to Address Water Scarcity*, PV MAG. (Feb. 6, 2020), https://www.pv-magazine.com/2020/02/06/a-new-solar-desalination-system-to-address-water-scarcity.

85 *See* Jeff Gifford, *Valley Water Technology Company Looks to Expand After $50M Cash Infusion*, PHX. BUS. J. (Jun. 23, 2020), https://www.bizjournals.com/phoenix/news/2020/06/23/zero-mass-water-company-gets-50m-in-funding.html (describing Zero Mass Water Inc.'s solar-powered "hydropanels," which can be used almost anywhere to extract water directly from the atmosphere).

86 *See generally* Peter H. Gleick, *Water and Energy*, 19 ANN. REV. ENERGY & ENV'T 267 (1994).

87 *See* Tristram O. West & Gregg Marland, *A Synthesis of Carbon Sequestration, Carbon Emissions, and Net Carbon Flux in Agriculture: Comparing Tillage Practices in the United States*, 91 AGRIC., ECOSYSTEMS & ENV'T 217 (2002) (describing carbon emissions from reliance on fossil fuel-powered farm machinery).

88 *See Renewable Electricity Growth is Accelerating Faster Than Ever Worldwide, Supporting the Emergence of the New Global Energy Economy*, IEA (Dec. 1, 2021), https://www.iea.org/news/renewable-electricity-growth-is-accelerating-faster-than-ever-worldwide-supporting-the-emergence-of-the-new-global-energy-economy.

developing countries by creating possibilities for off-grid, solar-powered cold storage of harvested agricultural crops. In an effort to drive these technologies forward, Global LEAP Awards recently launched a global "Off-Grid Cold Chain Challenge."[89] Some companies that earned prizes in the contest are already beginning to deploy modular off-grid cold storage units in Africa.[90] By dramatically reducing food waste at the point of harvest with very few carbon emissions, these units are already beginning to push out nexus tradeoff frontiers in portions of that continent.

3. Other Potential Positive-Sum Strategies

In addition to advancements in renewable energy and energy storage, several other technological innovations are creating opportunities to expand nexus tradeoff frontiers. For instance, "agriculture IoT" or "internet of things" markets, which are rapidly expanding across the world, are prompting farmers to adopt various "precision farming techniques" that employ sensors and other technologies to reduce the water and energy requirements associated with food production.[91] Likewise, civilian drone technologies could eventually assist in crop dusting and field monitoring in ways that help farms use less energy and emit less carbon to grow the same amount of food.[92] And it's likely that many

[89] *See UK Aid-Funded Off-Grid Cold Chain Challenge Winners Announced*, EFFICIENCY FOR ACCESS (Nov. 18, 2019), https://efficiencyforaccess.org/updates/uk-aid-funded-off-grid-cold-chain-challenge-winners-announced [hereinafter *UK Aid-Funded Challenge*]; *Off-Grid Cold Chain Challenge*, EFFICIENCY FOR ACCESS, https://efficiencyforaccess.org/ global-leap-ogccc (last visited Oct. 19, 2022).

[90] *See, e.g.*, Hannah Blair, *Stories from the Field: High Hopes for Off-Grid Cold Chain Solutions in Rural Kenya*, MEDIUM (Oct. 8, 2019), https://medium.com/efficiency-for-access/high-hopes-for-off-grid-cold-chain-solutions-in-rural-kenya-36ceb3ac6bc8; *see also* Feed the Future Partnering for Innovation, *Stopping Losses, Creating Gains: Partnering for Innovation and ColdHubs Reduce Post-Harvest Loss in Nigeria*, AGRILINKS (Apr. 14, 2020), https://www.agrilinks.org/post/stopping-losses-creating-gains-partnering-innovation-and-coldhubs-reduce-postharvest-loss.

[91] *See, e.g.*, *Agriculture IoT Market Worth $32.7 billion by 2027*, CISION: PR NEWSWIRE (Sept. 10, 2020), https://www.prnewswire.com/news-releases/agriculture-iot-market-worth-32-7-billion-by-2027—exclusive-report-covering-pre-and-post-covid-19-market-analysis-by-meticulous-research-301127488.html.

[92] *See* Megan O'Connor, *The Sky's the Limit, Literally: How Drones Can Help Protect the Environment*, GEO. ENV'T L. REV. ONLINE (2017) (describing a "range of beneficial functions" drones can serve in the agricultural sector and noting that

other potential synergistic interactions among WEF nexus resources will emerge as technologies advance further in the coming decades.

## III. POSITIVE-SUM NEXUS GOVERNANCE

Well-crafted policies can do much to accelerate the pace of innovation and capital investment needed to expand WEF nexus tradeoff frontiers across the world. Such policy activities focused on expanding and leveraging positive-sum WEF nexus interactions constitute what this Article calls "positive-sum nexus governance." Positive-sum governance should supplement rather than replace conventional zero-sum nexus governance, which remains essential to managing countless zero-sum interactions that continue to vex the planet. However, laws and policies that more intently promote positive-sum nexus solutions and strategies can ultimately diminish many zero-sum resource tradeoffs and have an under-recognized role to play in resource management. This Part III describes a few specific types of positive-sum nexus governance and then highlights two avoidable risks associated with it.

### A. Policy Strategies for Expanding Nexus Tradeoff Frontiers

The overarching goal of positive-sum nexus governance is to expand existing nexus resource tradeoff frontiers such that communities and nations are able to supply greater overall quantities of water security, energy security, food security, and decarbonization than was previously possible. As suggested above, policies that drive innovation and infrastructure investment aimed at leveraging targeted positive-sum relationships are key to expanding these frontiers. A diverse and growing collection of policy strategies is capable of unlocking such synergies among WEF nexus resources.[93] For brevity's sake, the following paragraphs provide just a few general categories of such strategies—many of which are already well-established and in

"the Association for Unmanned Vehicle Systems International predicts that 80% of drone use will be in agriculture").

[93] Positive-sum nexus governance may be characterized as a distinct type of "ecological modernization" strategy. For a basic introduction to the concept of ecological modernization and the growing literature surrounding it, *see generally* Martin Jänicke, *Ecological Modernisation: New Perspectives*, 16 J. CLEANER PROD. 557 (2008).

effective use in other policy settings. Hopefully, other researchers will build upon this modest introductory list in the coming years.

1. Reducing Policy Support for Zero-Sum Nexus Interactions

One basic way to promote investment in positive-sum nexus interactions is to decrease government support for resource-intensive activities that are not positive-sum. Restructuring agricultural subsidies to less-aggressively reward wasteful farming practices would be one plausible example of this type of positive-sum governance strategy. Existing federal agricultural programs in the United States and elsewhere clearly support the nation's important food production industry, but some aspects of these programs do so in ways that encourage excessive uses of water and energy.[94] Redesigning such programs to more aggressively promote resource efficiency in food production could incentivize farmers to invest more in innovation and infrastructure that would expand nexus tradeoff frontiers.[95]

There are countless ways agricultural support programs could be structured to reduce tradeoffs among nexus resources in the production of food. For instance, integrating additional location-specific elements into farm subsidy programs could better deter the cultivation of water-intensive crops in arid regions.[96] Policymakers

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94 Although agricultural subsidy programs in the United States are notoriously bloated, wasteful agricultural subsidy programs in India have also garnered attention in recent years. *See, e.g.*, Gordon C. Rausser & David Nielson, *Looking Ahead: Agricultural Policy in the 1990s*, 23 U.C. DAVIS L. REV. 415, 420–21 (1990) (arguing that agricultural subsidies encourage farmers to use natural resources at unsustainable rates); Emily Schmall & Karan Deep Singh, *Why India's Farmers Fight to Save a Broken System*, N.Y. TIMES (Mar. 23, 2021), https://www.nytimes.com/2021/03/23/world/asia/india-farmers-protest-subsidies.html.

95 Other writers have emphasized this need for U.S. farm support programs to better incentivize more environmentally sustainable agricultural practices. *See, e.g.*, Carey W. King et al., *Coherence Between Water and Energy Policies*, 53 NAT. RES. J. 117, 180 (2013) ("Reducing or eliminating support for farm inputs such as water, diesel fuel, fertilizers, electricity, and irrigation systems give farmers incentives to increase resource efficiency, rather than to withdraw fossil resources to maximize crop yields.").

96 Other writers have advocated for this type of approach. *See, e.g.*, Casey Clowes et al., *Thirsty for a Solution: Promoting More Efficient Water Use in the West*, 20 U. DENV. WATER L. REV. 65, 80–81 (2016) (describing potential location-based agricultural incentive programs designed to account for locational differences in water scarcity).

could also condition more agricultural subsidies on compliance with prescribed resource management standards, such as the greater use of strategically planted trees in some climates to shade crops in ways that increase crop yields and reduce irrigation needs.[97] Simply reducing the artificial rewards associated with certain zero-sum resource uses could nudge many actors toward more positive-sum activities.

2. Taxing Zero-Sum Nexus Strategies

Another potential positive-sum nexus governance strategy is to single out and directly tax zero-sum nexus interactions. Pigouvian tax theory supports the use of taxes to correct negative externality problems that would otherwise incentivize excessive amounts of the externality-plagued activity.[98] Taxing products and activities based on their propensity for zero-sum nexus impacts compels market actors to internalize more of the social cost of those impacts and can thus drive them toward more positive-sum resource management strategies.

"Virtual water" or "water footprint" taxes—analogous to carbon taxes[99]—are one example of a potential means of using tax policy to expand nexus tradeoff frontiers. By increasing the relative cost of water-intensive products and services, such taxes promote greater private investment in water-efficient technologies, products, and infrastructure. Suppose, for instance, that a country were to enact a new differential, per-kilo "water footprint" tax on meat products based on the estimated volume of water required to produce each type of meat.[100] Such a tax would increase the relative price of highly water-intensive beef products over poultry products,

[97] The U.S. federal government has enacted some incentive programs for tree planting on agricultural lands, although these programs have yet to have major impacts. *See* Andrea Armstrong et al., *Adoption of the Conservation Reserve Enhancement Program in the New York City Watershed: The Role of Farmer Attitudes*, 66 J. SOIL & WATER CONSERVATION 337, 337–43 (2011).

[98] *See* ARTHUR CECIL PIGOU, THE ECONOMICS OF WELFARE 172–203 (4th ed. 1932).

[99] *See generally* Gilbert E. Metcalf & David A. Weisbach, *The Design of a Carbon Tax*, 33 HARV. ENV'T L. REV. 499, 553 (2009).

[100] Scientists have been estimating the "water footprints" for meat and other food products for years. *See generally, e.g.*, P.W. Gerbens-Leenes, *The Water Footprint of Poultry, Pork and Beef: A Comparative Study in Different Countries and Production Systems*, 1–2 WATER RES. & INDUS. 25 (2013) (measuring the water footprints of beef, pork, and poultry).

thereby steering consumers toward poultry and ultimately shifting more private investment toward poultry production-related infrastructure.[101] By reshaping the food system to supply more poultry and less beef, such investments could likewise expand the nation's food-water nexus tradeoff frontier. Similar impacts might even be possible through water footprint taxes on clothing or other goods as a means of driving innovation aimed at reducing the amount of water embedded in household products.

3. Promoting Private Investment in Positive-Sum Nexus Strategies

Subsidies and incentive programs designed to increase private investment in specific positive-sum nexus strategies are arguably the most straightforward form of positive-sum nexus governance. For example, national and sub-national governments could introduce new tax credit or rebate programs purposefully designed to promote private investment in agrivoltaics projects, off-grid cold storage, or solar-powered groundwater pumps. Federal tax credit and rebate programs for renewable energy development have greatly accelerated private investment in those technologies in the United States over the past decade, and introducing similar programs targeting specific positive-sum strategies would likely have comparable effects.[102]

Subsidizing research aimed at identifying and developing positive-sum nexus strategies can obviously accelerate their advancement and deployment as well. In the United States, federal tax revenues already fund some such research through the country's National Renewable Energy Laboratory, including projects on agrivoltaics and floatovoltaics.[103] Numerous other countries,

[101] Beef has a significantly higher per-unit water footprint than poultry. *See id*. at 29–32, 35 (comparing beef water footprints to poultry water footprints).

[102] For a detailed look at the efficacy of federal tax credit programs on renewable energy growth in the United States and ideas on how to drive more private investment into renewable energy markets, *see generally* Felix Mormann, *Beyond Tax Credits: Smarter Tax Policy for a Cleaner, More Democratic Energy Future*, 31 YALE J. ON REGUL. 303, 319 (2014) ("The deployment data for both wind and solar power generation capacity suggest that tax credits have indeed been effective at promoting the deployment of renewable energy in the United States.").

[103] *See generally Benefits of Agrivoltaics Across the Food-Energy-Water Nexus*, NAT'L RENEWABLE ENERGY LAB'Y (Sept. 11, 2019), https://www.nrel.gov/news/program/2019/benefits-of-agrivoltaics-across-the-food-energy-water-nexus.html; Robert S. Spencer et al., *Floating Photovoltaic Systems: Assessing the Technical Potential of Photovoltaic Systems on Man-Made Water Bodies in the*

including India, have also proactively subsidized and encouraged research on new synergistic uses of nexus resources.[104] And even competitions such as the Global LEAP Awards have already begun to support innovations that leverage positive-sum nexus resource interactions.[105] Still, strengthening policy support in these and similar areas would further propel innovation and should thus be an integral element of positive-sum nexus governance.

### B. Pitfalls to Avoid

Although positive-sum WEF nexus governance can potentially do much to increase the availability of nexus resources, there are at least two noteworthy risks related to their use. Some positive-sum nexus interactions require more intensive use of an open-access resource, so policies that aggressively promote such interactions can unintentionally lead to overexploitation of that shared resource. Policymakers fixated on leveraging positive-sum interactions among water, food, and energy can also unwittingly ignore a proposed policy's potential impacts on *other* vital resources and policy goals. Consciously avoiding these risks is crucial to ensuring the success of any positive-sum nexus strategy.

#### 1. Triggering Overexploitation of an Open-Access Nexus Resource

One hidden danger in some types of positive-sum nexus strategies is the potential to cause over-use of shared nexus resources. When such policies greatly expand access to or reliance on an open-access resource, they can sometimes lead to its overconsumption and ultimate degradation.

A prime example of this overexploitation risk is the potential for solar-powered groundwater pump installations in underdeveloped rural regions to trigger the rapid depletion of underground aquifers. Such depletion risks recently emerged in connection with the India Ministry of New and Renewable Energy's

*Continental United States*, 53 ENV'T SCI. TECH. 1680 (2019) (floatovoltaic research is funded through U.S. National Renewable Energy Laboratory).

104 In particular, India's government has aggressively funded research related to the deployment of solar water pump technologies within that country. *See, e.g.*, Eshita Gupta, *The Impact of Solar Water Pumps on Energy-Water-Food Nexus: Evidence from Rajasthan, India*, 129 ENERGY POL'Y 598, 598 (2019).

105 The Off-Grid Cold Storage Challenge highlighted above is one example of this type of competition. *See UK Aid-Funded Challenge*, *supra* note 89.

Solar Pumping Program.[106] This program, which has heavily subsidized the installations of hundreds of thousands of solar groundwater pumps across India, has improved food security within the nation and has also reduced carbon emissions by replacing many diesel-powered pumps.[107] However, because solar-powered pumps are far less expensive to operate than their diesel-powered predecessors, solar pumps have led to over-pumping, inefficient water use, and noticeably depleted groundwater supplies in some areas.[108]

Risks for this type of overexploitation tend to arise primarily in open-access resources such as groundwater that are already prone to "commons tragedies."[109] The growing problem of toxic algal blooms linked to nitrogen-rich fertilizers is another example of how a strategy aimed at expanding the WEF nexus can have negative-sum effects when scaled up over time.[110] Devastating algal blooms are often attributable, at least in part, to farmers' use of fertilizers and irrigation systems aimed at increasing food production and improving water conservation.[111] Lakes and ponds are the open-access resources that suffer from overexploitation in these contexts.[112]

Fortunately, it is often possible to mitigate or avoid these overexploitation risks when rolling out new policies aimed at promoting positive-sum nexus interactions. For instance, in the case of solar groundwater pump policies, regulating pump sizes, requiring sensors on pumps that monitor use, and imposing per-unit extraction charges can all potentially deter over-pumping.[113] Using additional solar energy to power water-conserving electrified

[106] *See* Gupta, *supra* note 104, at 598, 608.
[107] *See id.* at 598–99.
[108] *See id.* at 598, 608.
[109] For a discussion of the tragedy of the commons, *see* Garrett Hardin, *The Tragedy of the Commons*, 162 SCI. 1243, 1244–45 (1968).
[110] *See generally* Benjamin Bryce & Robert Skousen, *Bloomin' Disaster: Externalities, Commons Tragedies, and the Algal Bloom Problem*, 21 U. DENV. WATER L. REV. 11, 20–23 (2017) (noting that "fertilizers for crops . . . also promote the growth of aquatic algal blooms" and that "increased use of freshwater for agricultural irrigation [has] raised salinity levels in numerous water bodies," thereby contributing to algal blooms).
[111] *See id.* at 20–22.
[112] *See id.* at 14–15, 18.
[113] *See* Gupta, *supra* note 104, at 608.

irrigation systems may likewise further help reduce solar pumps' impacts on groundwater supplies in some settings.[114]

2. Ignoring Impacts on Non-Nexus Resources and Policy Priorities

One other potential hazard of positive-sum WEF nexus governance is the risk that it might divert policymakers' attention away from other important resource management issues and policy goals. As useful as fixating on positive-sum strategies involving food, water, and energy may be, they can obscure such strategies' adverse effects on other pressing policy objectives.

Examples of this type of hidden risk abound. For instance, hydroelectric dams have long been a type of positive-sum nexus interaction because of their potential to expand all three "arms" of the WEF nexus while also reducing carbon emissions. Hydroelectric projects generate low-carbon electric power and their reservoirs can often improve water security and assist with late-summer crop irrigation as well.[115] However, hydropower projects' potential impacts on biodiversity are far less rosy. Their well-documented harms to wild salmon populations in the Pacific Northwest region of the United States exemplify this downside.[116] Framing hydropower projects solely as a positive-sum WEF nexus strategy ignores these other significant costs.

Zealously promoting positive-sum nexus interactions can also divert governments' attention away from other indispensable policy commitments such as environmental justice, cultural preservation, and social justice. Accounts of the devastating impacts of wind energy projects on Indigenous communities in Southern Mexico and

[114] *See id.* at 608.

[115] *See* David Steves, *Study: Dams Help the NW Cope With Climate Change*, OR. PUB. BROAD. (Sep. 25, 2013), https://www.opb.org/news/article/study-dams-help-the-nw-cope-with-climate-change (describing an academic study highlighting the benefits of Columbia River hydroelectric dams for late summer crop irrigation).

[116] *See generally* Michael C. Blumm et al., *Still Crying Out for a "Major Overhaul" After All These Years—Salmon and Another Failed Biological Opinion on Columbia Basin Hydroelectric Operations*, 47 ENV'T L. 287 (2017) (describing adverse impacts of hydroelectric dams in the Pacific Northwest on salmon populations); *Hydropower*, STATE OF SALMON IN WATERSHEDS, https://stateofsalmon.wa.gov/executive-summary/challenges/hydropower-and-dams (last visited Mar. 4, 2023).

elsewhere are important reminders of these risks.[117] Like any WEF nexus governance decision, positive-sum strategies must be carefully vetted to ensure that any impacts falling outside of the WEF nexus construct are not so great as to supersede any perceived benefits to nexus resources.

Fortunately, in many cases with creativity and purposeful effort, it is possible to design policies that encourage positive-sum nexus resource interactions without incidentally undermining other policy priorities. One strategy for doing that is to allocate a portion of the incremental value created through a newly exploited positive-sum interaction toward other targeted policy goals. For example, many renewable energy developers voluntarily contribute to specific social causes in communities that house their projects. The energy company Ørsted took this approach when it announced plans in 2019 to create a "Pro-NJ Trust [F]und" in connection with the company's development of a New Jersey wind farm in the Northeastern United States.[118] Grants from this $15 million fund will specifically support women- and minority-owned small businesses seeking involvement in the region's "emerging offshore wind energy industry."[119] The United States hydropower industry similarly struck a deal in late 2020 with United States wildlife advocacy groups that will allow the industry to increase fish-friendly power generation at certain existing dams in exchange for cooperation in the permanent removal of several other non-generating dams that have long harmed fish populations.[120] Government matching grant programs,[121] robust mitigation

[117] *See* TROY A. RULE, SOLAR, WIND AND LAND: CONFLICTS IN RENEWABLE ENERGY DEVELOPMENT 128–31 (2014) (describing adverse impacts of unwelcome wind farm development on subsistence living and cultural resources of Indigenous communities in Oaxaca, Mexico).

[118] *See New Jersey Selects Ocean Wind for State's First Offshore Wind Project*, BUS. WIRE (June 21, 2019, 12:47 PM), https://www.businesswire.com/news/home/20190621005393/en/New-Jersey-Selects-Ocean-Wind-State's-Offshore.

[119] *See id.*

[120] *See* Brad Plumer, *Environmentalists and Dam Operators, at War for Years, Start Making Peace*, N.Y. TIMES (Oct. 13, 2020), https://www.nytimes.com/2020/10/13/climate/environmentalists-hydropower-dams.html.

[121] *See, e.g.*, Bipartisan Sportsmen's Act of 2015, S. 405, 114th Cong. § 204 (2015) (describing proposed federal legislation that would have created three-to-one matching grants to organizations, municipalities, and private landowners for acquiring, restoring, and enhancing wetlands critical to migratory bird populations).

requirements,[122] and other policies that mandate or incentivize such conscious allocations of the new value created through positive-sum nexus interactions can help to ensure other policy priorities do not get ignored in efforts aimed at promoting water, energy, and food security.

## CONCLUSION

As developing economies and the impacts of climate change place more and more pressure on the planet's finite water, energy, and food supplies, the WEF nexus framework serves as an important reminder of the need to effectively manage interactions among these crucial resources. However, the nexus framework highlights more than just a complex web of difficult tradeoffs among nexus resources. Increasingly, it also reveals the potential for synergistic new interactions among food, water, and energy systems—interactions capable of stretching existing resource supplies and thereby advancing sustainability goals. This "positive-sum" view of the WEF nexus embodies the growing reality that innovation and targeted infrastructure investment can unleash cooperative new interactions among nexus resources. In particular, solar photovoltaics technologies are increasingly creating opportunities for such positive-sum nexus relationships, making it possible to improve food and water security while also generating low-carbon electric power. Although such opportunities admittedly don't exist yet in many contexts or presently face political obstacles, defining positive-sum nexus governance is a crucial first step toward integrating this distinct ecological modernization strategy into the broader global sustainability movement. By accelerating the development and deployment of these and other positive-sum nexus strategies, policymakers can spare future generations from facing many difficult resource tradeoffs in the decades to come.

122 *See generally* Amy Wilson Morris & Jessica Owley, *Mitigating the Impacts of the Renewable Energy Gold Rush*, 15 MINN. J.L. SCI. & TECH. 293, 311 (2014) (identifying various ways for mitigation requirements to help protect wildlife preservation and other efforts in the context of renewable energy development).